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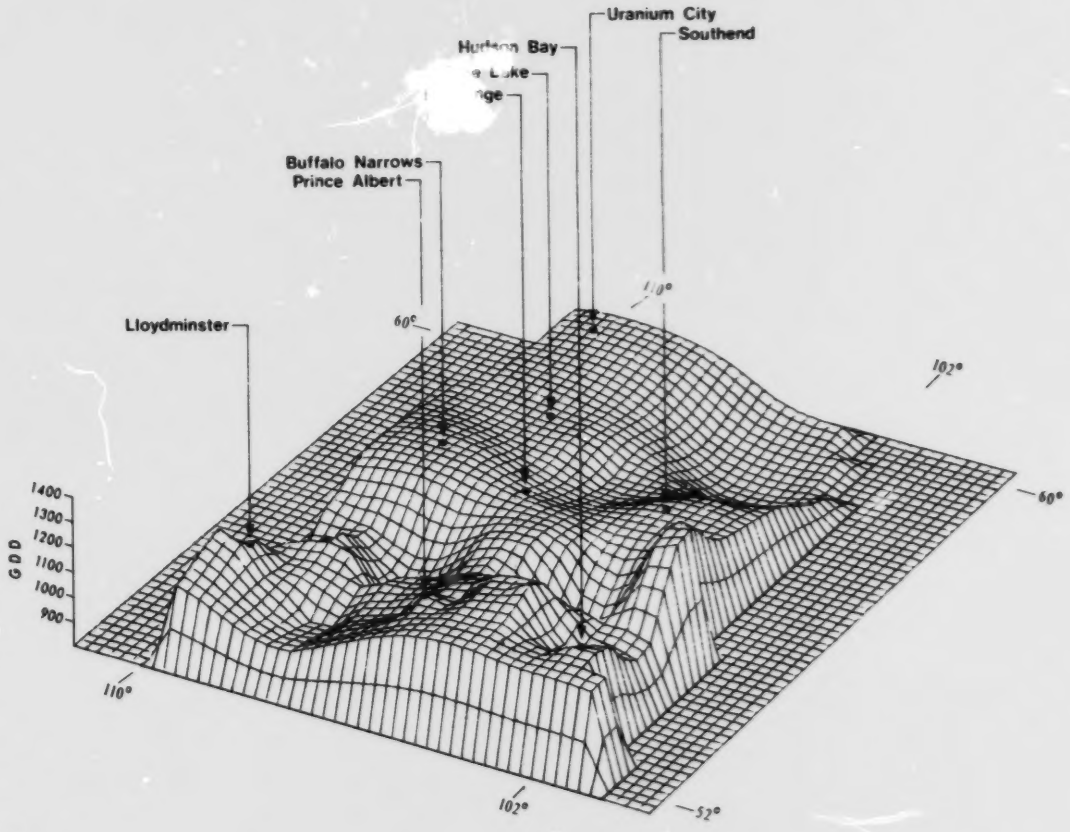

KB

COVER

Our cover illustrates the cumulative growing days for the frost free season in 1984 in northern Saskatchewan.

Government of Saskatchewan
Department of Agriculture
Room 43, Legislative Building
REGINA, Saskatchewan

FOREWORD

The 1984 issue of Saskatchewan Wild Rice Research (ISSN 0825-964X) is the second of our yearly publications of Saskatchewan studies on wild rice.

The Government of Saskatchewan is totally committed to the fullest development of the wild rice industry in the Province. The Department of Agriculture is prepared to use the necessary resources to ensure that it takes place.

The research reports in this issue are wide ranging - from related environmental factors such as water, sediment and climate as well as to growing requirements, crop care and harvesting.

Some studies are preliminary, but were undertaken because they are necessary steps in our quest for full knowledge of the particular research subject.

As we move ahead firmly towards the full development of the wild rice industry in Saskatchewan, we are conscious of the fact that our research efforts, such as the studies that appear in this year's issue, will have helped make each step possible.

Lorne H. Hepworth
Minister of Agriculture

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RESEARCH REPORTS (1984) SUMMARY

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Department of Agriculture

The accompanying reports have all been condensed but extreme care was used to ensure that the contents of each study remained completely intact. Full text of each report is kept by the Northern Agriculture Unit and may be made available to growers and researchers upon request.

Some of the studies are preliminary and readers are cautioned on some of the findings of the researchers.

Growers will benefit from the completion of the study on "Wild Rice-Environment Relationships and the Regional Potential for Northern Saskatchewan". Bert Weichel and Dr. Bill Archibold, who worked on the subject for the last two years, have now come forward with findings which will be very interesting and useful to both new and old growers. They revealed specific intrasite habitat considerations such as water and sediment factors as crucial in the successful commercial production of wild rice. They also revealed very significant distinction on growth and production in different areas relative to its position to the precambrian shield. As well, they have attempted to identify in general category, the degree of commercial adoption of wild rice in the different regions of northern Saskatchewan.

The study on "Variations in Wild Rice Morphology and Productivity Across Northern Saskatchewan" was conducted in response to growers' concern. Many growers feel that the intrasite existence of different wild rice varieties may be

a factor in the low harvesting recovery. In the accompanying initial report of Dr. Bill Archibold and Bert Weichel, they revealed significant differences in the over-all plant performance in the different regions of the province as well as in a specific site itself. The next phase of the study will be an attempt to determine whether the initial distinct variation will continue to manifest even if grown in different regional settings on a uniformly controlled situation.

Harvesting continues to be a major concern of the industry. During harvesting operation, growers see for themselves the extent of the percentage of grains that fell into the water instead of the bucket. The need for a much more effective and efficient harvester is indeed critical. The Agricultural Engineering Department, University of Saskatchewan, designed and constructed a unit which was an attempt to introduce a new approach on harvesting. Field evaluation of the unit, however, did not come out as efficient as hoped. Dr. Lal Kushwaha revealed some of the problems he encountered, but at the same time obtained valuable information which he hopes to use for further studies.

The Northern Agriculture Unit was able to undertake applied research projects in 1984 as well. One study was designed to monitor as closely and intensively possible major environmental factors. Specifically, the study attempted to determine the effect of water quality and depth, sediment type and contents, to plant growth and production. One interesting result was the apparent important influence of phosphorus on growth and production, such as what had been found in a recent study in Manitoba. Since the lake that was studied represents a very common size and type of lake in northern Saskatchewan, we hope, the growers will find our observation very useful in their respective development program.

The Northern Agriculture Unit also undertook a study which dealt with the thinning of wild rice at the floating leaf stage. Thinning has always been thought of by established growers in northern Saskatchewan, as a means to reduce very heavy plant density, which eventually led to poor plant growth and low yield. It is in fact extensively practiced in paddy wild rice production. In cooperation with an established grower - Mercer River Rice Ltd., the thinning equipment was evaluated, and the effect of thinning on growth, tillering performance and production were studied. The growers will find our findings and observations very interesting and hopefully useful.

WILD RICE-ENVIRONMENT RELATIONSHIPS AND THE REGIONAL POTENTIAL FOR NORTHERN SASKATCHEWAN

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Introduction

The impact of widespread wild rice introduction on the region north of the Northern Administrative District (NAD) boundary (Figure 1) can as yet only be roughly approximated. The essential purpose of this geographically extensive study, initiated in June, 1983, has been to contribute to understanding the eventual size of, and limitations for, the wild rice industry. First, known wild rice habitat served as a base for identifying environmental conditions, plant performance and varieties present. Secondly, regional climate was examined to determine whether unsuitable portions could be identified and the risk of serious frost damage estimated. The final part is a first approximation of how wild rice habitat capability is distributed within the region.

Section 1: Wild Rice Habitat and Plant Performance

1.1 Objectives and Methods

Limited ecological research on wild rice had been done in Saskatchewan prior to initiation of the present study. The plant does not grow equally well in all types of conditions, therefore the objectives in the first section of the study were:

-to obtain data on environmental conditions and wild rice growth from a diversity of habitats over a wide area

-to determine if intraregional differences exist between habitat types

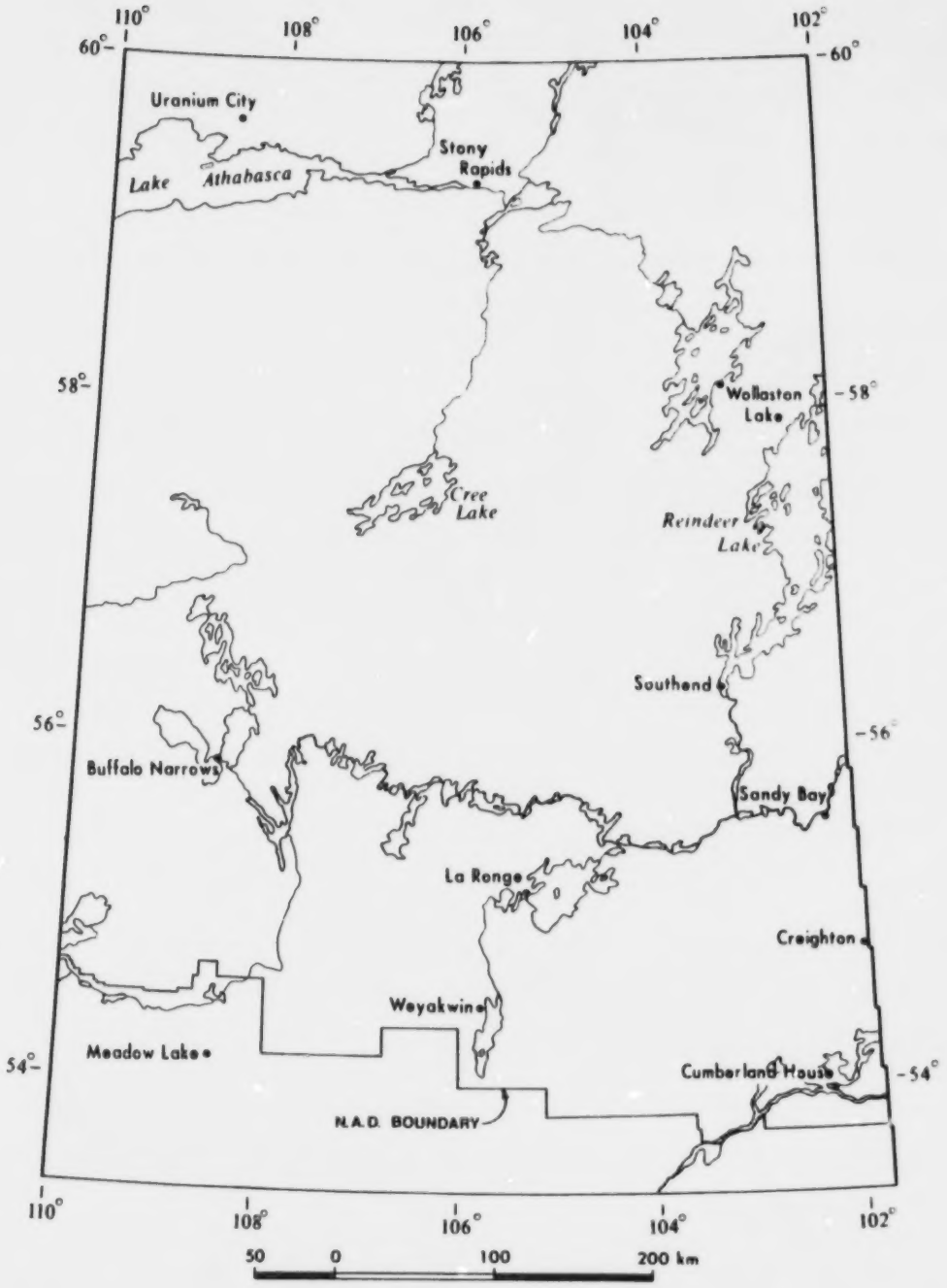

Figure 1. The study region: northern Saskatchewan.

-to determine if wild rice varieties can be identified which may be best suited to particular habitats.

Most wild rice is currently grown south of 56° N. Measurements and collections (Table 1) were made at 36 sites, located both north of the Precambrian Shield margin, and to the south, in waters on glacial drift-covered sedimentary bedrocks (Figure 2). Lake (shorelines and bays) and stream (channels and mouths) habitats were included in each of eastern, central and western sampling areas (Figure 3). The majority of the field data are from 9 sampling stations per site (324 stations total). Morphological measurements were made on 1820 stems collected at the stations.

1.2. Intrareqional Variations in Environmental Factors and Wild Rice Growth

A regional profile of habitat conditions and plant performance is contained in Tables 2 and 3 respectively. For some variables broad ranges and relatively high standard deviations indicate the extent to which "typical" conditions can be characterized. Cross-regional gradients are evident in a number of habitat variables, including water depth, pH, conductivity, and alkalinity as well as most of the measures of wild rice growth (Table 4). The results suggest that productivity was decidedly greater in the western area with an eastward decline, however these differences must be considered in the context of the other habitat types.

1.2.1 Lake/Stream Habitat Grouping

Table 5 compares stations in bays or along shores of lakes and those in stream channels and mouths. While there was no significant difference

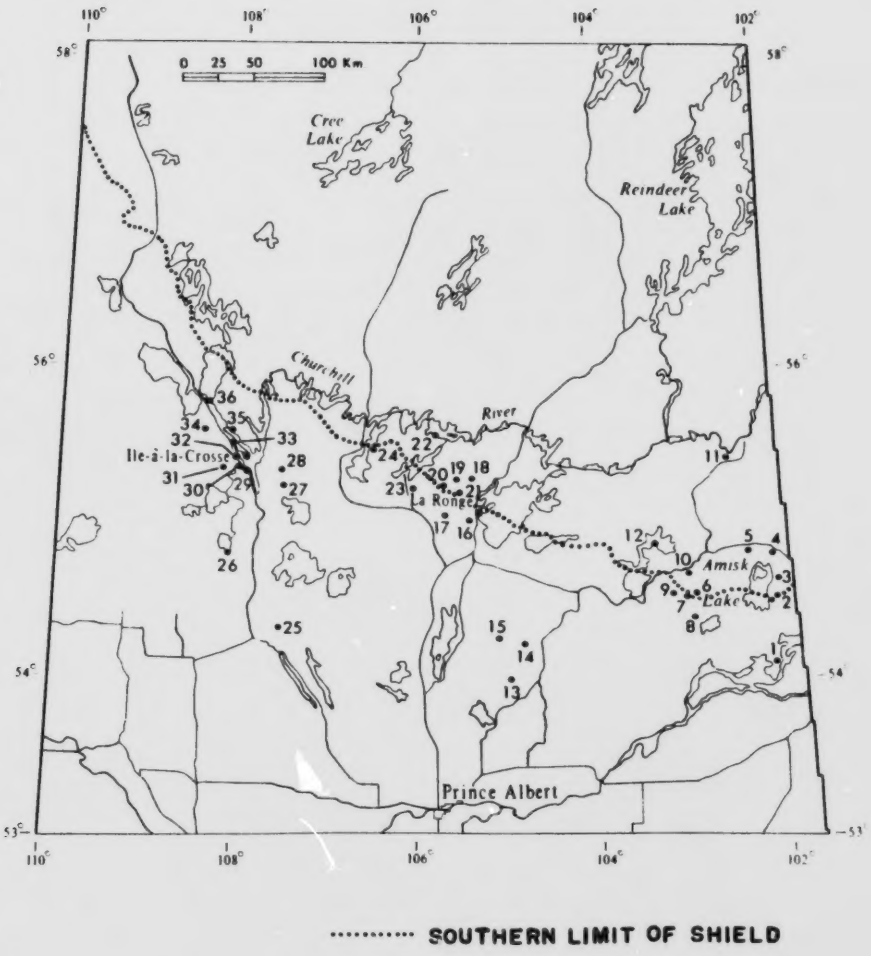

Figure 2. Location of 36 sites at which sampling stations were established.

TABLE 1. VARIABLES MEASURED AT SAMPLING STATIONS (n=324)

Water	Sediment	Wild Rice
-depth	-depth	-mature stem density
-pH	-pH	-plant & seed weight[1]
-conductivity	-wild rice thatch	-leaf, flower & stem sizes
-temperature	-macronutrients[2] (NH_4^+ & NO_3^- nitrogen, inorganic phosphorus, $SO_4^=$ sulphur	-% tiller stems
-dissolved O_2		-female florets
-alkalinity		

[1] plant measurements obtained for samples from sampling stations, except seed weights based on composite samples for entire sites

[2] analysis was done on 3-station composite samples from inshore, midway and lakeward (lake sites) or bank, midchannel and opposite bank (stream sites) station combinations.

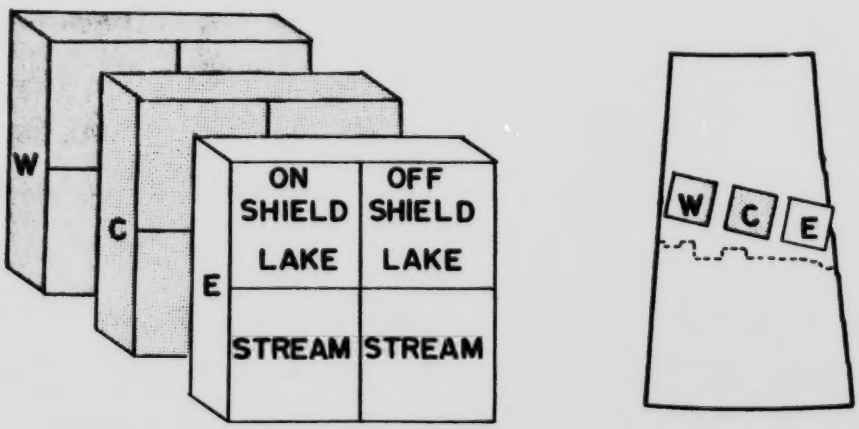

Figure 3. Framework used to differentiate habitats within the current main wild rice growing areas.

TABLE 2. DISTRIBUTION OF WATER AND SEDIMENT VARIABLES FOR ALL SAMPLING STATIONS*

VARIABLE	MEAN	ST.DEV.	MINIMUM	MAXIMUM	MEDIAN
Water					
depth (cm)	92.9	35.8	19.0	191.0	100.0
pH	7.67	0.62	6.40	9.40	7.50
conductivity (uS cm^{-1})	144.8	66.6	42.0	280.0	143.5
temperature (^{o}C)	19.8	2.3	13.5	25.0	20.0
dissolved O_2 (mg l^{1})	7.3	2.8	1.4	14.0	7.4
total alkalinity (mg l^{1} $CaCO_3$)	87.8	41.7	15.0	180.0	92.5
Sediment					
depth[1] (cm)	66.2	26.4	10.0	101.0	62.0
pH	6.41	0.28	5.63	7.46	6.44
thatch[2]	0.7	1.4	0.0	6.0	0.0
NH_4^+-N (mg l^{1})	53.9	32.1	10.0	165.0	45.0
NO_3^--N (mg l^{1})	4.4	6.3	0.1	26.5	1.8
$P_{inorganic}$ (mg l^{1})	5.8	7.1	1.0	46.0	4.0
K (mg l^{1})	90.7	39.1	35.0	215.0	80.0
SO_4-S[3] (mg l^{1})	-	-	15.0	-	-

*Based on composite samples for 3-station transects, 3 per site (n=108)

[1]At 24% of stations firm substrate was an undetermined amount greater than 100 cm and was recorded as 101 cm. For stations with depth < 100 cm the mean was 54.7 cm.

[2]Amount of thatch cover over sediment was assigned values between 0 (nil) and 6 (very heavy)

[3]All $SO_4^=$-S values except 2 were greater than 20 mg l^{1} and actual values are not known; one value of 15.0 and another of 16.0 were

TABLE 3. DISTRIBUTION OF WILD RICE VARIABLES FOR ALL SAMPLING STATIONS

VARIABLE	MEAN	ST.DEV.	MINIMUM	MAXIMUM	MEDIAN
stem density (m^{-2})	62.2	59.8	0.3	372.0	52.0
weight per stem[1] (g, dry)	2.7	1.6	0.2	8.1	2.3
seed weight[2] (mg)	44.0	9.0	18.0	60.0	45.0
biomass[3] (kg ha)	2,932.7	2,800.0	7.3	16,880.7	2,206.7
max. yield[4] (kg ha)	1,647.4	1,838.6	2.7	12,037.9	1,128.5
stem unit wt. (g m^{-1})	1.9	1.2	0.3	9.9	1.6
total stem length (cm)	147.0	32.2	57.0	230.3	149.2
internodes per stem	3.9	0.4	2.5	5.0	3.9
total flower length (cm)	40.5	7.6	20.7	58.8	40.9
female flower length (cm)	20.1	5.0	9.3	39.4	19.5
female florets per head	36.8	22.7	6.0	153.4	30.6
floret density[5] (cm^{-1})	1.8	0.9	0.4	5.7	1.5
leaf width[6] (mm)	13.8	3.9	5.3	24.8	13.6
% tiller stems[7]	35.9	31.1	0.0	93.8	33.3
productivity index[8]	89.5	107.7	2.4	794.3	44.7

[1]Includes roots, stems, leaves and flowers; excludes seeds. All weights oven dry.

[2]Determined as mean (3 replicates of 100) from composite sample for site (9 sampling stations).

[3]Based on entire plant including seed.

[4]Estimate of potential maximum fresh weight (40% moisture) seed yield; assumes 100% pollination and seed maturity.

[5]Number of female florets per cm of female flower length.

[6]Width of aerial leaf sheath. Determined as mean from 2 uppermost leaves per stem.

[7]Includes all tillers arising from root mass and stem nodes.

[8]Derived from stem unit weight. x number of female florets.

TABLE 4. MEAN VALUES FOR EAST (n=108), CENTRAL (n=108) AND WEST (n=108) SAMPLING AREA GROUPS

Variables[1]	EAST	CENTRAL	WEST
Water:			
depth	111.3	108.5	58.9
pH	7.30	7.76	7.94
conductivity	102.0	142.8	189.5
temperature	18.3	21.1	19.9
dissolved O_2	7.8	7.8	6.3
alkalinity	62.4	84.0	117.2
Sediment			
depth	62.5	68.9	67.1
pH	6.31	6.44	6.52
thatch	0.8	1.4	0.1
NH_4^+-N	58.8	46.5	55.7
$NO_3^=$-N	5.7	4.2	3.4
$P_{inorganic}$	3.2	9.0	5.6
K	120.3	84.7	66.6
Wild rice			
stem density	54.9	74.7	57.1
seed weight	39.0	50.0	44.0
biomass	1,859.4	2,763.3	3,906.2
max. yield	1,050.3	1,446.4	2,242.1
stem unit wt.	1.0	1.8	3.0
stem length	161.4	137.3	141.8
female florets	25.7	29.3	55.9
floret density	1.3	1.5	2.6
leaf width	11.9	12.6	16.9
% tillers	22.2	25.8	60.4
prod. index	31.2	64.7	175.4

[1] see Tables 2 & 3 for units of values

in water pH, streams were somewhat lower in temperature and dissolved O_2 and nearly 20% shallower than lakes. Slightly lower dissolved mineral contents in lake waters were seen in conductivity and alkalinity values. Except for depth of loose, rooting zone deposits and levels of phosphorus, sediment conditions were significantly if not drastically different between the two groups. Ammonium nitrogen and potassium levels were less in lakes; the reverse was true of pH and nitrate nitrogen. Reduced

accumulations of wild rice thatch in the stream sites could reflect more continuous flow or periodic flushing in such locations.

Differences in plant morphology and productivity were notable; except for similarity in height the plants from streams were more robust, producing greater amounts of vegetation, with potentially more (albeit lighter) seeds found on more crowded flower heads. The productivity index, determined as stem unit weight (g m^{-1}) x female floret numbers, was almost twice as great for stream habitat, with large differences also in the derived values for biomass and estimated maximum yield.

1.2.2 Shield Groupings

In Table 6 the comparison between on- and off-Shield stations shows even more marked disparities for the majority of variables than in the lake/stream grouping. In addition to being close to two-thirds as deep, the off-Shield stations reflected the effects of physiography and surficial geology on water quality in their higher pH, and in conductivity and alkalinity values on the order of 2.5 times above on-Shield locations. More oligotrophic conditions would be expected to affect sediment chemistry and rates of organic decomposition. A higher value for thacth was in fact found in the on-Shield group; nitrogens and potassium were higher and inorganic phosphorus levels less than half those for locations off-Shield.

In terms of wild rice growth only mean stem density and seed weight differences were insignificant. Stem lengths show the on-Shield plants to be taller, possibly in response to the deeper water. The remaining variables indicate that the off-Shield specimens, though shorter, are

TABLE 5. MEAN VALUES FOR LAKE (n=189) AND STREAM (n=135) HABITAT GROUPS[1]

Variables[2]	LAKE	STREAM
Water:		
depth *	101.6	80.9
pH	7.67	7.66
conductivity (*)	138.2	154.0
temperature *	20.1	19.4
dissolved O_2 *	8.0	6.3
alkalinity (*)	83.3	94.2
Sediment		
depth	66.7	65.5
pH (*)	6.46	6.37
thatch (*)	0.9	0.5
NH_4^+-N (*)	50.4	58.6
$NO_3^=$-N (*)	5.2	3.4
$P_{inorganic}$	5.9	5.7
K *	82.2	102.1
Wild rice		
stem density (*)	55.0	72.2
seed weight *	46.0	41.0
biomass *	2,520.9	3,503.7
max. yield (*)	1,434.1	1,933.0
stem unit wt. *	1.7	2.1
stem length	146.4	148.0
female florets *	30.6	45.7
floret density *	1.5	2.1
leaf width *	12.8	15.6
% tillers *	31.1	42.7
prod. index *	65.1	124.9

[1]differences between station groupings
* $p < 0.01$ (*) $p < 0.05$
[2]see Tables 2 & 3 for units of values

TABLE 6. MEAN VALUES FOR ON-SHIELD (n=108) AND OFF-SHIELD (n=216) HABITAT GROUPS[1]

Variables[2]	On-Shield	Off-Shield
Water:		
depth *	120.4	79.2
pH *	7.24	7.88
conductivity *	73.1	180.7
temperature	19.7	19.8
dissolved O_2	7.6	7.2
alkalinity *	41.9	110.8
Sediment		
depth	66.3	66.1
pH *	6.24	6.53
thatch *	1.3	0.4
NH_4^+-N *	66.5	48.1
$NO_3^=$-N (*)	32.6	5.0
$P_{inorganic}$*	2.9	7.2
K *	107.7	82.9
Wild rice		
stem density	61.1	62.7
seed weight	44.0	44.0
biomass *	1,993.0	3,483.0
max. yield *	1,112.9	1,931.9
stem unit wt. *	1.1	2.3
stem length *	157.1	141.6
female florets *	22.1	44.7
floret density *	1.2	2.1
leaf width *	11.3	15.1
% tillers *	21.8	43.4
prod. index *	27.6	122.9

[1]differences between station groupings
* $p < 0.01$ (*) $p < 0.05$
[2]see Tables 2 & 3 for units of values

stockier and exhibited significantly more vigor. On-Shield values for biomass, maximum seed yield, stem unit weight, number of female florets and percent tiller stems were approximately half those of the off-Shield group. Most of the additional floret production in the latter was due to more crowded flower heads. Combined floret and vegetative differences resulted in an off-Shield productivity index value nearly 4.5 times greater than for on-Shield stations.

1.2.3 A Complete Habitat Type Framework

A hierarchy in which on-Shield lakes in the eastern area are least productive, ranging to the most productive off-Shield streams in the west, is inferred from the foregoing comparisons (Figures 4a and 4b). The productivity index increases westward for each of on-Shield lake, off-Shield lake and off-Shield stream habitats. There are also progressions in leaf width, stem unit weight, and female floret number and density. Off-Shield lakes in the central area had a comparatively high productivity index. This would seem to have been due to proportionally greater vegetative growth; female floret density remained below that of off-Shield streams in the central area. Misclassification of sites may be involved because of difficulties inherent in discerning on- from off-Shield sites in close proximity to the Shield margin. Streams and lakes presented similar difficulties at influent points.

1.3 Discussion

The results confirm Dore's (1969) suggestions that optimal wild rice growth is found in the constant flow of streams, and that suboptimal performance occurs in waterbodies on the granitic Precambrian Shield.

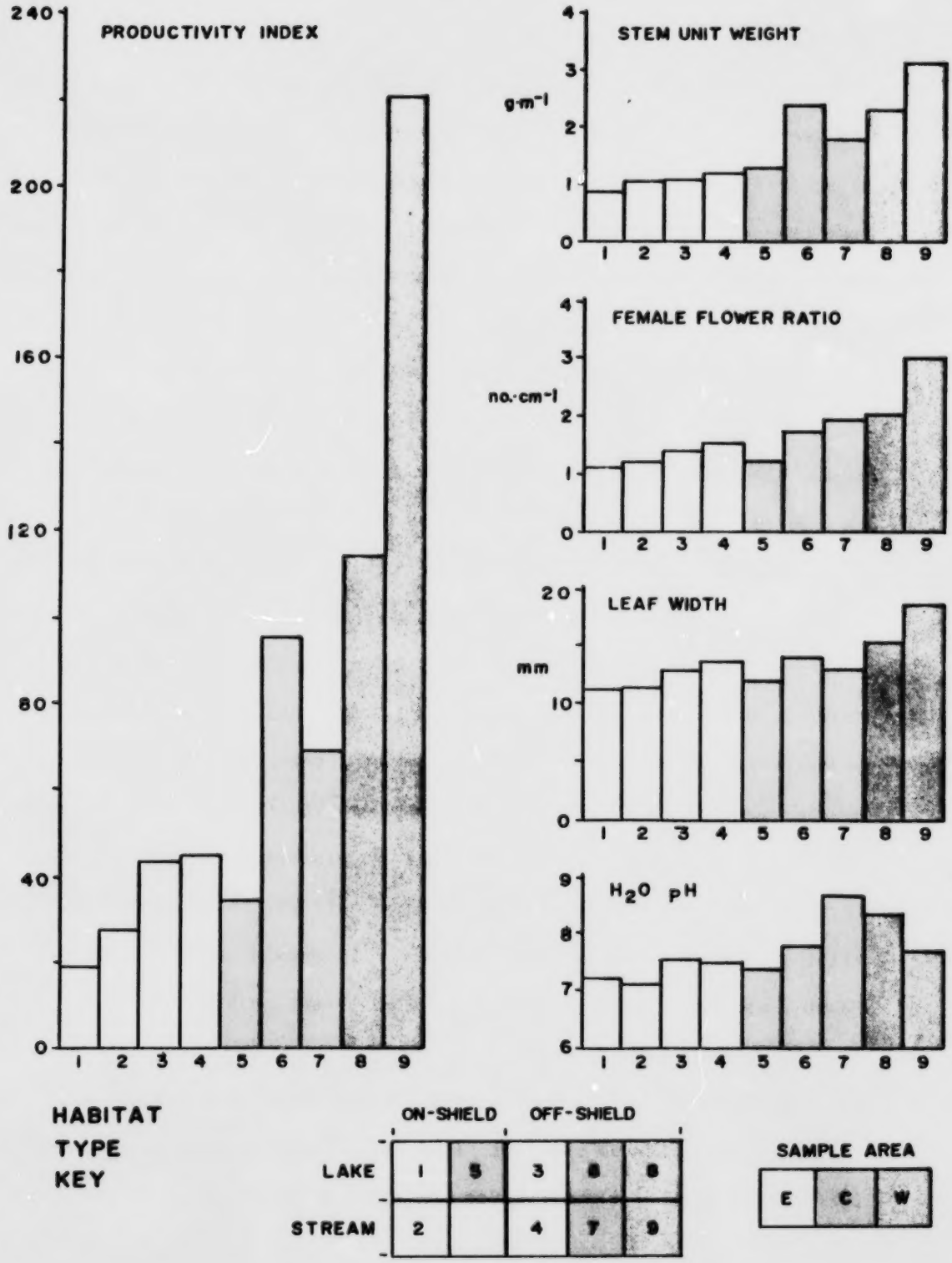

Figure 4a. Mean values of selected variables in the habitat types.

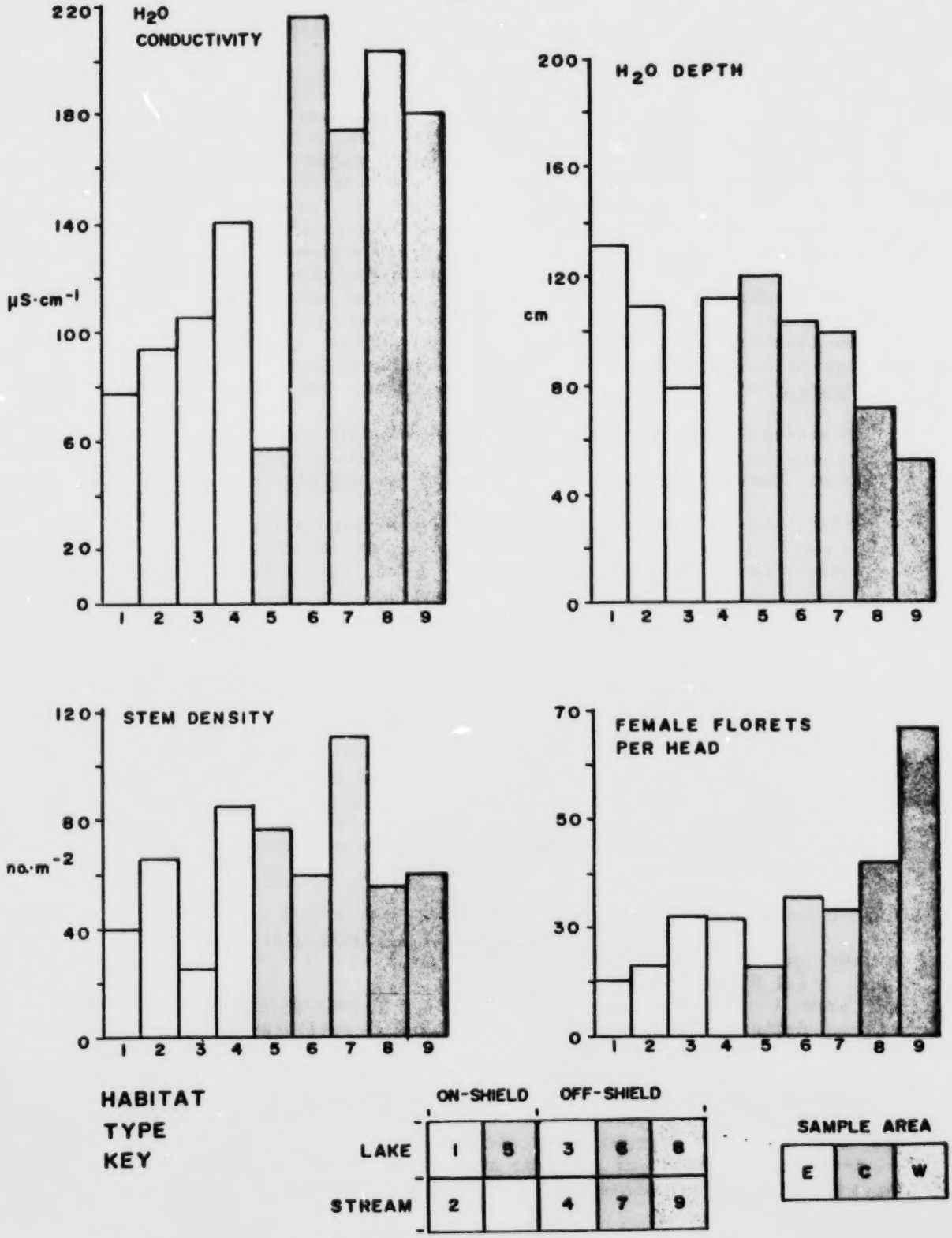

Figure 4b. Mean values of selected variables in the habitat types. (cont.)

Reasonably close agreement was obtained with data from northwestern Ontario (Counts, 1984), as for example in on-Shield values (Table 6) for number of female florets (22.1), stem unit weight (1.1 g m^{-1}), leaf width (11.3 mm) and productivity index (27.6); the Ontario values (our estimates) are 30.2, 1.1, 9.9, and 31.0 respectively.

Morphology of plants collected at several western area sites matched the taxonomic details for Interior wild rice (Zizania palustris var. interior or "river rice") provided by Dore. Incidental specimens from outside sampling stations, collected on exposed mud 10-15 cm above water level, measured up to 19 female florets per panicle branch, 36 mm leaf width, and 282 cm stem length. The regional population may consist of an intervarietal mix, with expressed morphology largely a response to environment. Northern wild rice (Z. palustris var. palustris or "lake rice") is considered to be predominant, especially in the central and eastern areas. However, the larger, more productive Interior variety may do poorly in suboptimal habitat and appear more "lake-rice-like". Further research is warranted as a prerequisite to basic seed selection efforts aimed at matching seed sources to conditions in potential new sites.

Section 2. Estimation of Climatic Limitations

2.1 Objectives and Methods

A crucial requirement of wild rice is a sufficiently long and warm growing season that the plants may reach maturity in advance of fall frosts. Within the constraints of above-freezing temperatures the growing season must consist of a regime of heat and light sufficient to meet the

metabolic requirements of the species. Wild rice is less affected by late spring frosts because initial growth is submerged. This introduces problems in applying frost-free period length directly. The plant is more susceptible during the 10-14 day maturation period in late August-early September at a time when the probability of frost is increasing daily. In 1982 heavy frost damage was widespread in the study region and at many locations caused virtually complete crop losses. Therefore the objectives in this section were:

-to define a northern climatic limit for successful, long term production of wild rice

-to attempt to determine the comparative risk of serious frost damage to the crop.

Methodology was restricted by the relatively sparse amount of climatic and phenological data available for the region. Initiation of harvest for 1967-1983 (courtesy of Kaz Parada, La Ronge Industries Ltd.) was used as an indication of when wild rice crops reached maturity. This enabled temporal distribution of maturity date to be estimated for the central area of the major production zone (south of the Churchill River). Monthly mean temperatures provided a basis for estimates of amount of heat and heat/light (photothermal) units accumulating over the growing season. Heat units were calculated as growing degree-days (GDD) above base $5^{o}C$ using: [GDD = (mean monthly temp. -5^{o}) X no. of days] summed for May to September inclusive. Photothermal units (PTU) incorporate day lengths at a station's latitude using: [PTU = monthly GDD X mean day hrs.] summed for May to September inclusive. Minimum daily temperatures (complete record

years only) were used to determine frost-free period and to compute variations in fall frost dates at 2 stations.

2.2 Results and Discussion

The data (Table 7) are consistent with the existence of a northeastward decline in the thermal regime (Wheaton 1979). Figure 5 shows frost-free period. Accumulated heat as GDD is shown in Figure 6; values decrease from about 1300 GDD near the NAD boundary to less than 900 GDD north and east of Wollaston Lake and Stony Rapids. Close coincidence is seen between the 1000 GDD line and the line for 100 frost-free days. Figure 7 depicts the distribution of photothermal units and strongly resembles the GDD pattern. A decline of over 600 PTU occurs, from 20,000 in the south to under 14,000 in the northeast.

Earlier incidence of fall frost should accompany the northeastward progression toward a shorter season and cooler regime. Mean fall frost dates were determined to be September 7 (Julian day 251.24; standard deviation 12.92) for La Ronge and August 24 (Julian day 237.20; standard deviation 12.77) for Stony Rapids. Mean date of wild rice maturity was August 26 (Julian day 239.00; standard deviation 5.77). Assuming frost occurrence and wild rice maturation to be independent and normally distributed variables, probabilities may be depicted as cumulative relative frequencies portrayed over time (Figure 8). Line PWRM represents the probability, for a given date, that the wild rice crop has not yet matured. Lines PFSR (Stony Rapids) and PFLR (La Ronge) give the probability that the first fall frost has already occurred. Magnitude of severe frost damage risk is shown by the area beneath the intersecting

TABLE 7. SUMMARY OF VALUES RELATED TO GROWING SEASON THERMAL REGIME

Key to stations and positions
(degrees and minutes N, W)

ML-Meadow Lake[a]	54 08, 108 26
BN-Buffalo Narrows	55 51, 108 30
FF-Creighton[b]	54 45, 101 54
LR-La Ronge	55 06, 105 17
CH-Cumberland House	53 58, 102 16
SB-Sandy Bay[c]	55 33, 102 18
WD-Whitesand Dam	51 27, 102 40
BL-Brabant Lake	56 00, 103 43
CL-Cree Lake	57 22, 106 50
UC-Uranium City	59 34, 108 36
SR-Stony Rapids	59 16, 105 50
CB-Collins Bay	58 17, 103 39

[a]peripheral to study region
[b]recording station at adjacent Flin Flon
[c]recording station at adjacent Island Falls

Variable		Stations ML	BN	FF	LR	CH	SB	WD	BL	CL	UC	SR	CB
frost-free days	1.	111	129	----	104	----	103	94	----	100	108	89	----
	2.	115	110	----	90	110	104	92	----	106	109	73	----
growing degree days (GDD)	3.	1340	1189	1294	1165	1380	1119	970	1024	1089	1022	875	716
	4.	1359	1194	----	1148	1386	1150	1034	----	978	1085	948	----
	5.	1071	1135	----	925	----	939	777	----	879	974	716	----
	6.	659	606	----	442	----	508	309	----	282	555	142	----
photothermal units (PTU x 100)	7.	209	189	203	185	215	177	154	162	157	167	142	116
	8.	131	138	----	114	----	113	94	----	106	117	89	----

Sources

1. Determined from daily minimum temperatures for years of complete record. Records 15 years or more except SR (5 yrs), BN (8 yrs), & CR (12 yrs).
2. Wheaton 1979.
3. Determined from mean monthly temperatures (1951-80). Base 5°C.
4. As in 2. Base 5°C.
5. As in 1. Values are "minimum accumulated GDD". Base 0°C.
6. As in 5. Base 5°C.
7. As in 3. Employs monthly mean day length for station latitude.
8. As in 1. Values are "minimum accumulated photothermal units". Base 0°C.

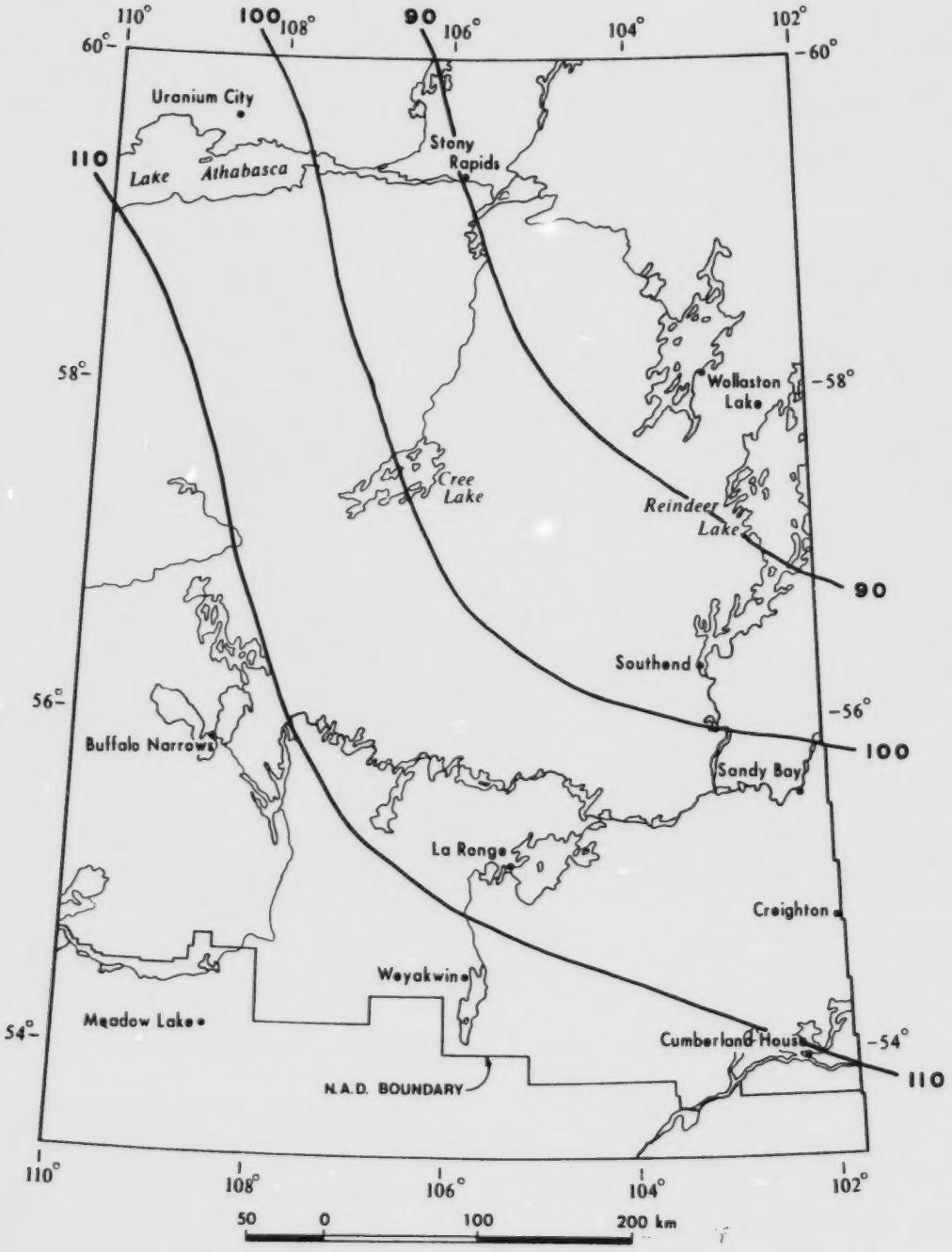

Figure 5. Mean frost-free period.

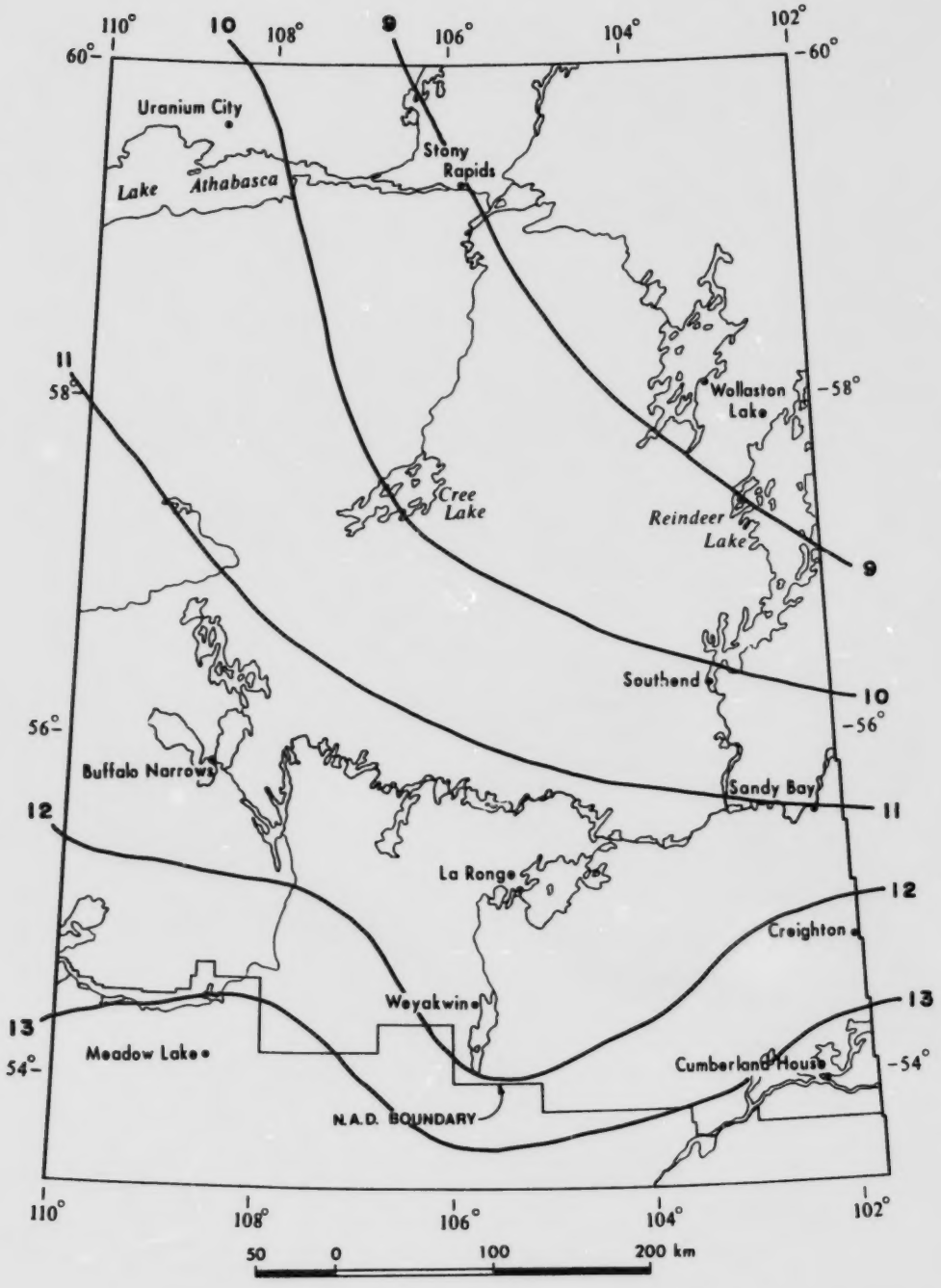

Figure 6. Mean growing degree days (GDD x 100)

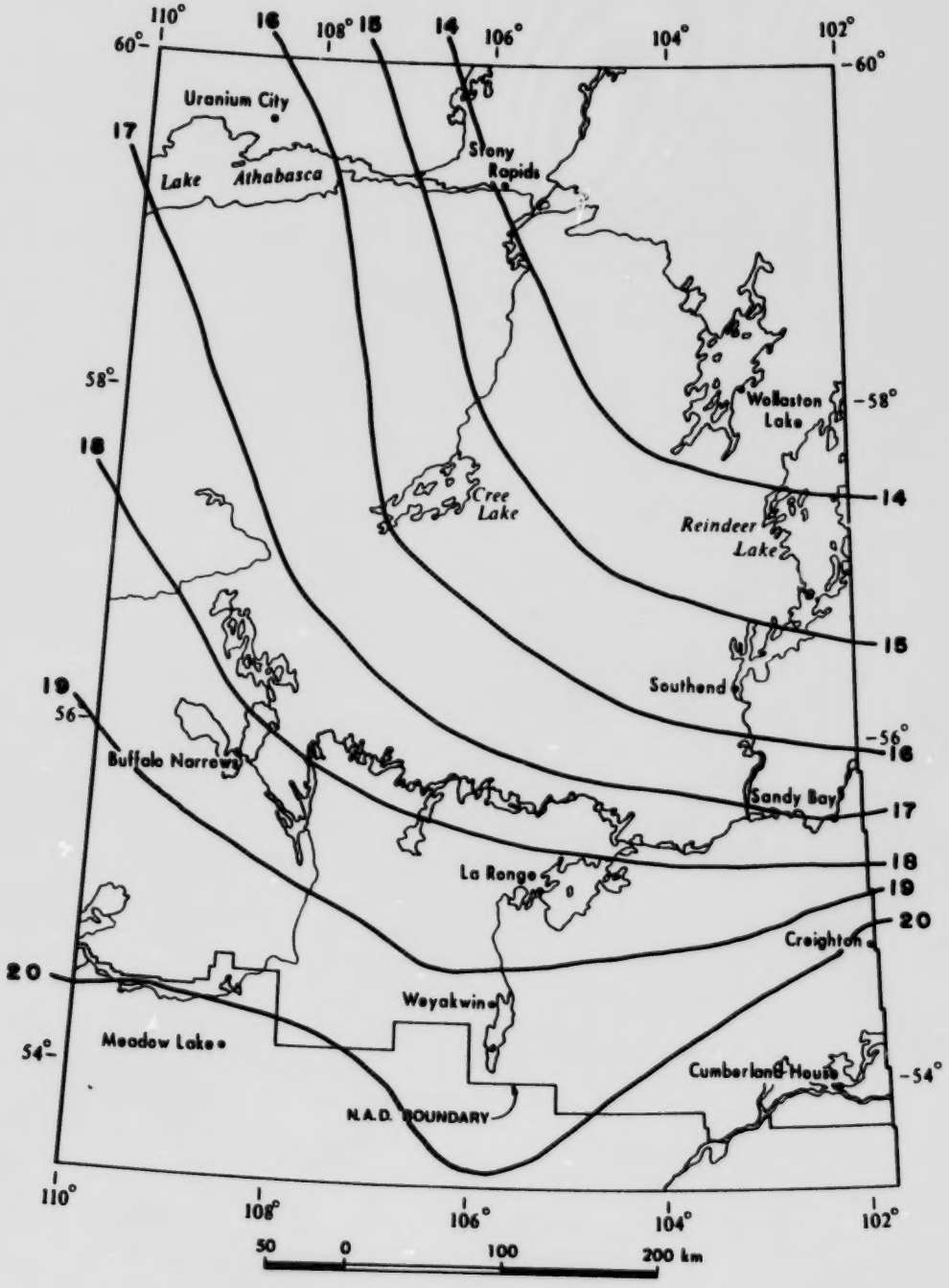

Figure 7. Mean photothermal units (PTU x 1000)

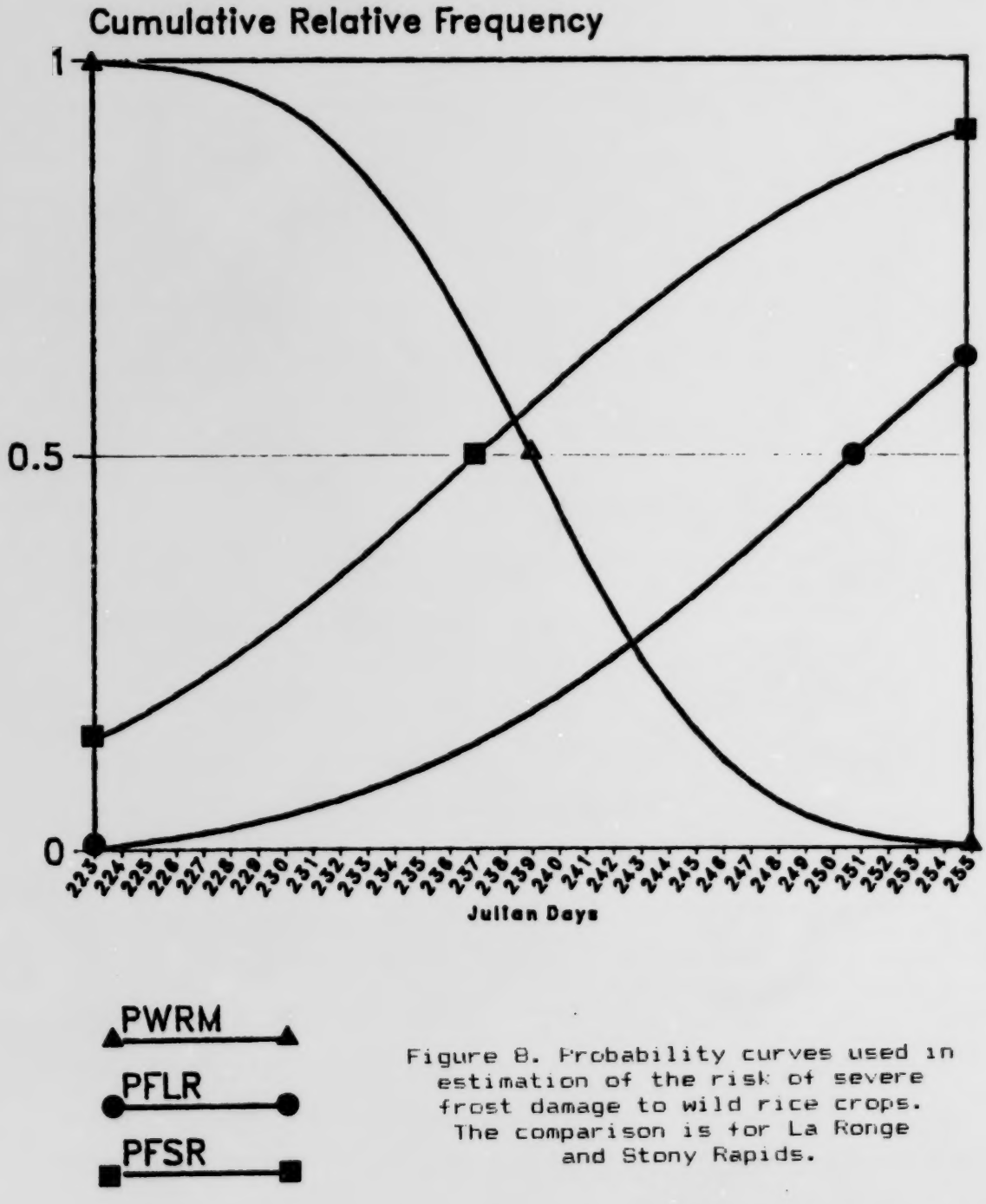

Figure 8. Probability curves used in estimation of the risk of severe frost damage to wild rice crops. The comparison is for La Ronge and Stony Rapids.

curves; the value calculated for La Ronge was 18.5%and for Stony Rapids 42.9%.

The findings characterize the regional temperature environment and provide a basis for estimating the extent to which climate may be a limitation for wild rice production in northern Saskatchewan. Since both temperature and light are growth determinants it is appropriate, in comparing latitudinally distant areas, to employ photothermal units. A mean of approximately 21,200 PTU accumulated over an average 109 day life cycle of wild rice in Minnesota at around 47^{0} north (Grava et al 1977-1982). Frontier stands mapped by Lee (1977) in northwestern Ontario include outliers near 51^{0} N in a zone of approximately 17,500 PTU. The majority of Saskatchewan wild rice is found between 54^{0} and 56^{0} N; PTU values in that latitudinal zone are mainly in the 17,000-20,000 range, with virtually all known stands located southwest of the 16,000 PTU isoline (Figures 7 and 9). This implies that wild rice growth may be marginally feasible even in the area north of Lake Athabasca; weak-stemmed specimens bearing few florets were retrieved from the vicinity of Uranium City in 1983.

Although beyond the scope of the presentstudy it is anticipated that wild rice growth rates and performance might be found to differ with declining PTU accumulations. Counts (1983) discussed a latitudinal gradient which included northward acceleration through phenological stages, coincident with reductions in seed numbers and vegetative dimensions. It may be possible that morphological differences described in Section 1 are in some measure related to photothermal regime. However it

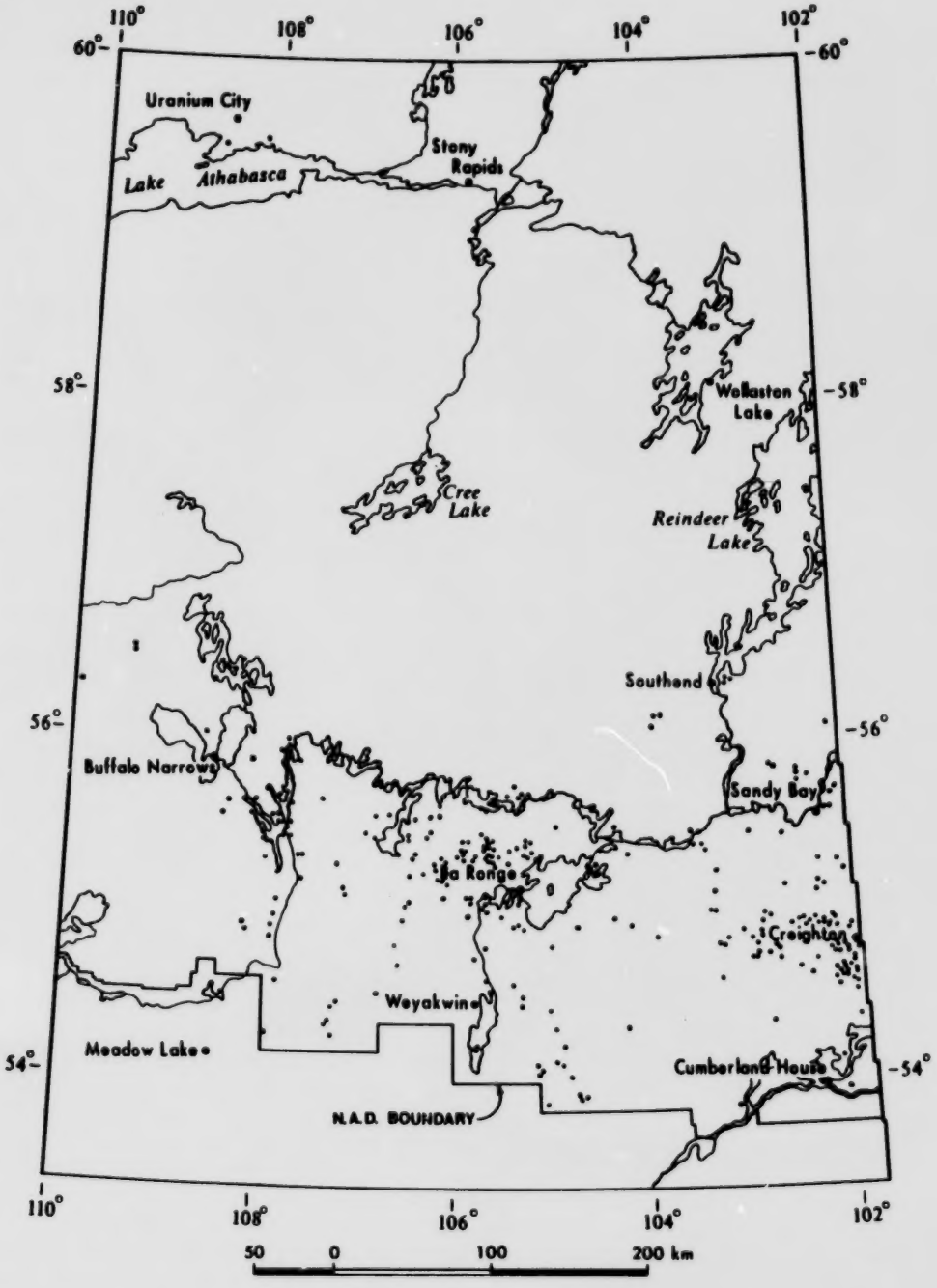

Figure 9. Distribution of wild rice stands in northern Saskatchewan (Sept. 1984)

is not known if, or to what extent, climate operates synergistically with other habitat conditions. A northern margin of climatic suitability is considered to exist approximately in the 15,500-16,000 PTU band shown in Figure 7, a conclusion corroborated by a paucity of established wild rice stands beyond that isoline in Saskatchewan or elsewhere. Within the portion deemed suitable serious harvest reductions due to early fall frost are estimated to be on the order of a once in 5 years event, with higher frequencies expected to occur close to the northern margin.

Section 3. Assessment of Intraregional Potential

3.1 Objectives and Methods

The region has been shown to be heterogeneous in terms of habitat conditions and wild rice productivity. A further step involves subdividing northern Saskatchewan to outline more internally uniform growing areas.The main objectives have been:

- -to map an effective northern limit for feasible production of wild rice
- -to delineate subregions or districts within whose boundaries the habitat potential for wild rice is reasonably consistent
- -to identify in general terms what the major limitations are considered to be, as well as what the relative potential is among the subregions or districts.

Size of the study region, amount and detail of pertinent information, and broad objectives necessitated use of an Ecological Land Classification (ELC) approach. ELC methodology is integrative, involving a heirarchy of levels of generalization. A diversity of interrelated criteria can be used

in mapping areal units at various scales (Wiken et al 1982). The application in the present study is a variant of ELC to the extent that emphasis was on use of climate, physiography (Acton et al 1960), surficial geology (Pearson and Whitaker 1972), and limnology (Liaw and Atton 1981, Koshinsky 1970), as classification criteria, while no attempt was made to utilize such criteria as terrestrial flora and fauna. Extensive use was made of topographic maps (1:500,000 and 1:250,000) in concert with satellite imagery (Landsat: band 6 B/W prints and false colour transparencies of bands 4,5,7; both at 1:500,000). The operative scale of the classification was the ecoregion/ecodistrict levels of generalization.

3.3 Results and Discussion

Figure 10 summarizes the outcome of the classification and mapping procedures. A northern margin was set primarily on the basis of the climatic analysis (section 2), while recognizing that effects such as those due to water chemistry may add further environmental constraints (section 1). The margin can be seen to conform closely to the 15,000-16,000 PTU band depicted in Figure 7. The region covers approximately 297,000 km^2 and 98,750 km^2 (33.2%) have been excluded as unsuitable for wild rice. For 198,250 km^2 (66.8%) a total of 27 districts are identified. The scheme strongly reflects 4 principal physiographic divisions: the granitic/volcanic/metamorphic and sandstone areas of the Precambrian Shield; and the mainly drift-mantled lowlands/plains and uplands south of the Shield margin.

Liaw and Atton identified a southwest to northeast gradient of declining waterbody nutrient status through 3 zones. The area off the

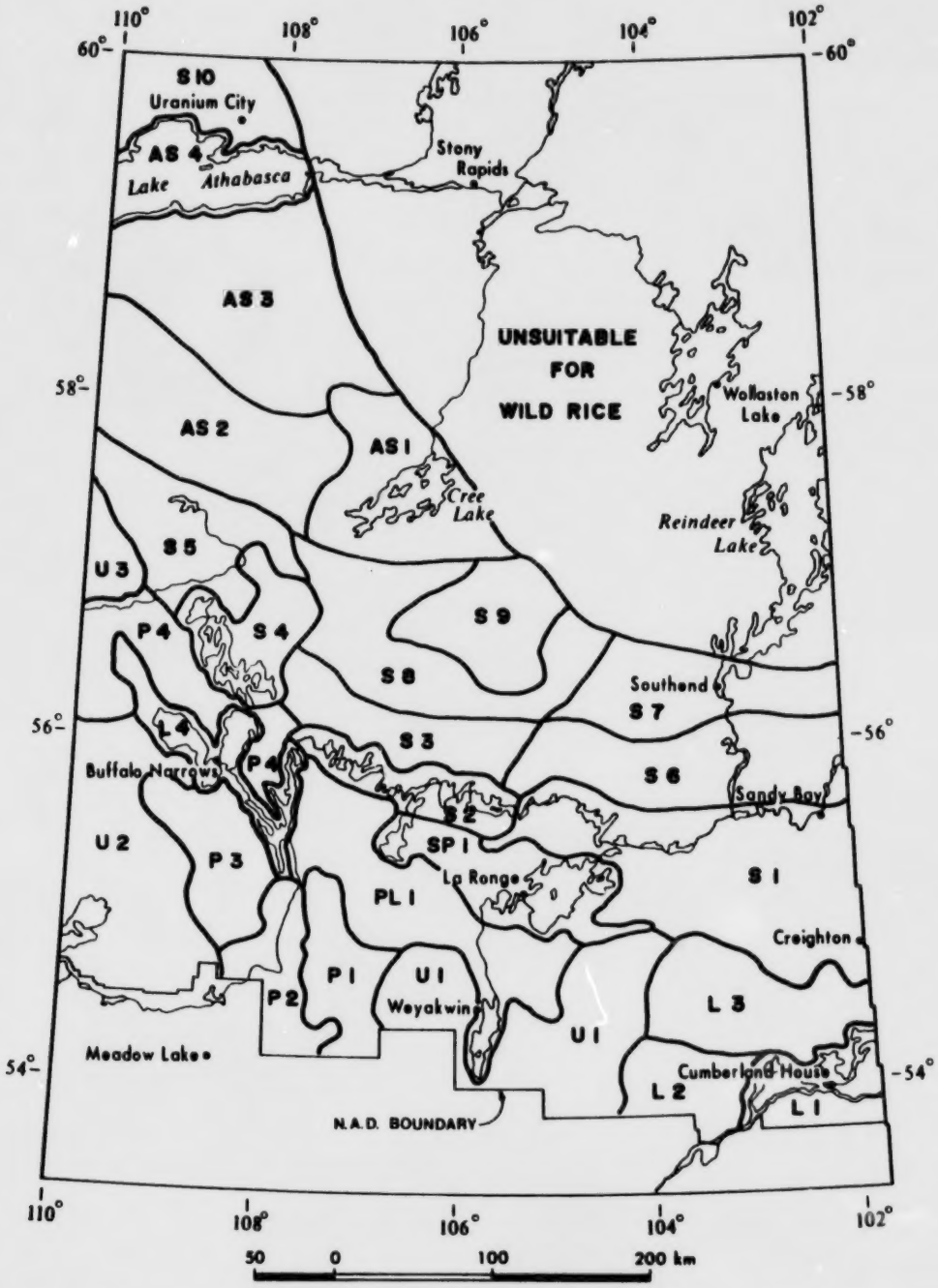

Figure 10. Classification of the study region into growing districts on the basis of general limitations for habitat potential

Shield (Figure 2) has mean pH, total dissolved solids (TDS) and alkalinity values of 8.01, 166 mg l^{-1} and 124 mg l^{-1} respectively. These values fall to 7.39, 76 and 38 respectively for the more southerly Shield zone, which extends north to a line approximated by the 17,000 PTU isoline (Figure 7). To the northeast the respective values are 7.12, 40 and 15. (Estimated mean conductivities for the zones are 266, 122 and 64 uS cm^{-1} from south to north.) Suboptimal wild rice growth could be associated with the more oligotrophic conditions on the Shield (section i). Many aspects of regional hydrology, including drainage patterns, stream gradients and lake densities, as well as basin forms are dependent upon physiography and landform genesis. Features such as lake size and configuration are apparent on maps and imagery and provided classification criteria relevant to the potential amount of surface water situated over shallow littoral areas (Koshinsky).

Quantitative estimates of actual hectares cannot as yet be made with any degree of confidence. Nonetheless the classification provides a framework for evaluating intraregional potential and the comparative contribution of districts to the wild rice industry as a whole (Table 8). Applications in planning, monitoring and management are also possible. For example, Figure 11 shows the pattern of permit locations as of September, 1984, although cancellations and approval of new permits is ongoing. Comparison of Figures 9, 10, and 11 reveals that various relatively "unused" districts are also ones which have been assigned lower habitat capabilities, a fact with significant implications for future expansion of the wild rice industry.

TABLE 8. GENERAL CAPABILITY AND AREAL EXTENT OF DISTRICTS

District	RATING	Area (km^2)	%of Total Area
AS1	very poor	9,091	4.6
AS2	"	11,516	5.8
AS3	"	15,607	7.9
AS4	nil	6,211	3.1
S1	fair	17,198	8.7
S2	"	4,318	2.2
S3	"	5,455	2.8
S4	"	3,023	1.5
S5	"	7,045	3.6
S6	poor	9,773	4.9
S7	"	6,970	3.5
S8	"	9,925	5.0
S9	"	5,757	2.9
S10	"	5,000	2.5
L1	fair	3,789	1.9
L2	"	3,789	1.9
L3	good	7,500	3.8
L4	fair	4,545	2.3
PL1	good	11,061	5.6
SP1	"	6,591	3.3
P1	fair	4,166	2.1
P2	good	3,789	1.9
P3	"	5,302	2.7
P4	"	6,364	3.2
U1	poor	10,909	5.5
U2	"	11,743	5.9
U3	"	1,818	0.9
	Total	198,255	100.0

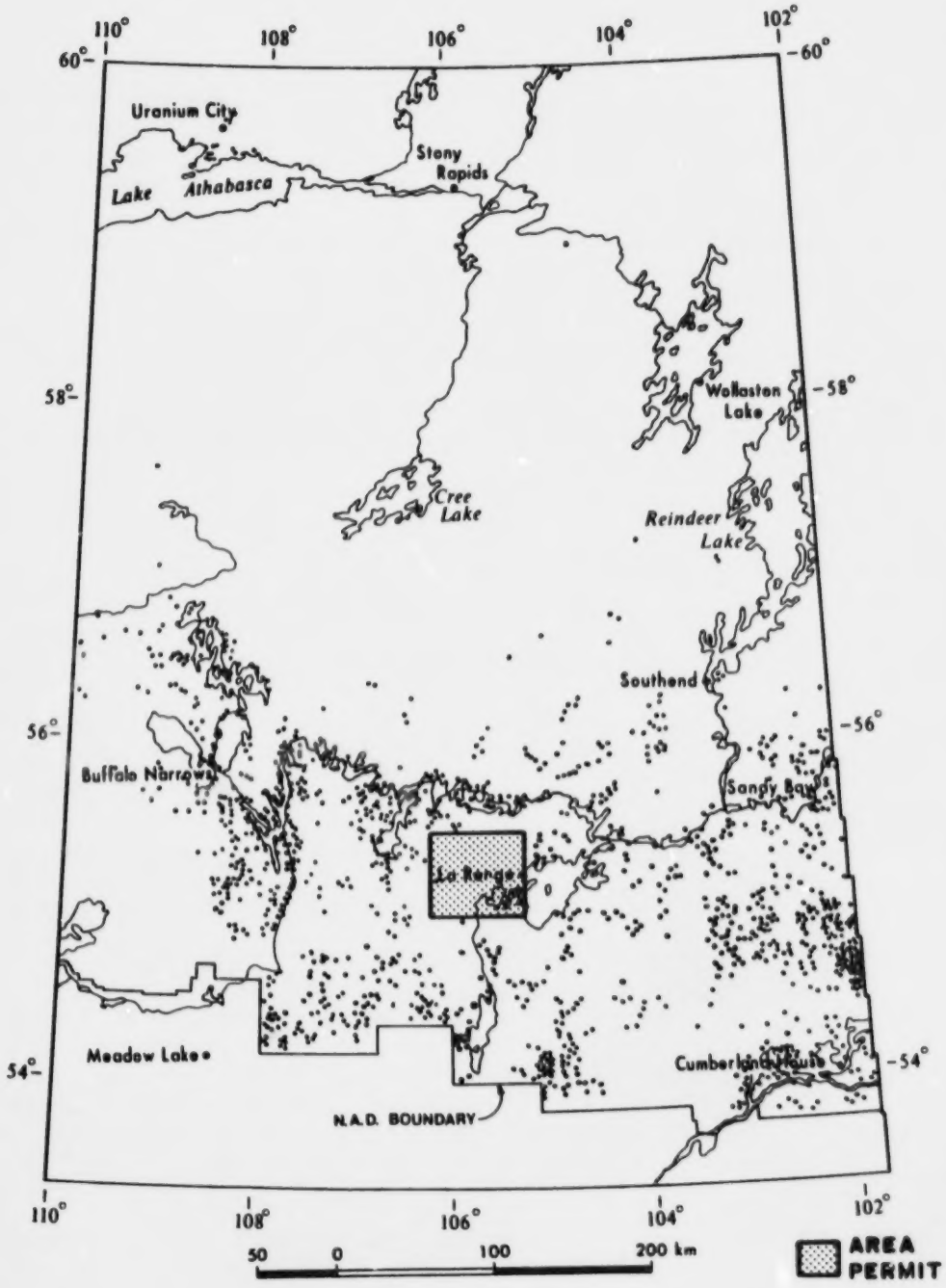

Figure 11. Distribution of wild rice permits (Sept. 1984)

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VARIATIONS IN WILD RICE MORPHOLOGY AND PRODUCTIVITY ACROSS NORTHERN SASKATCHEWAN

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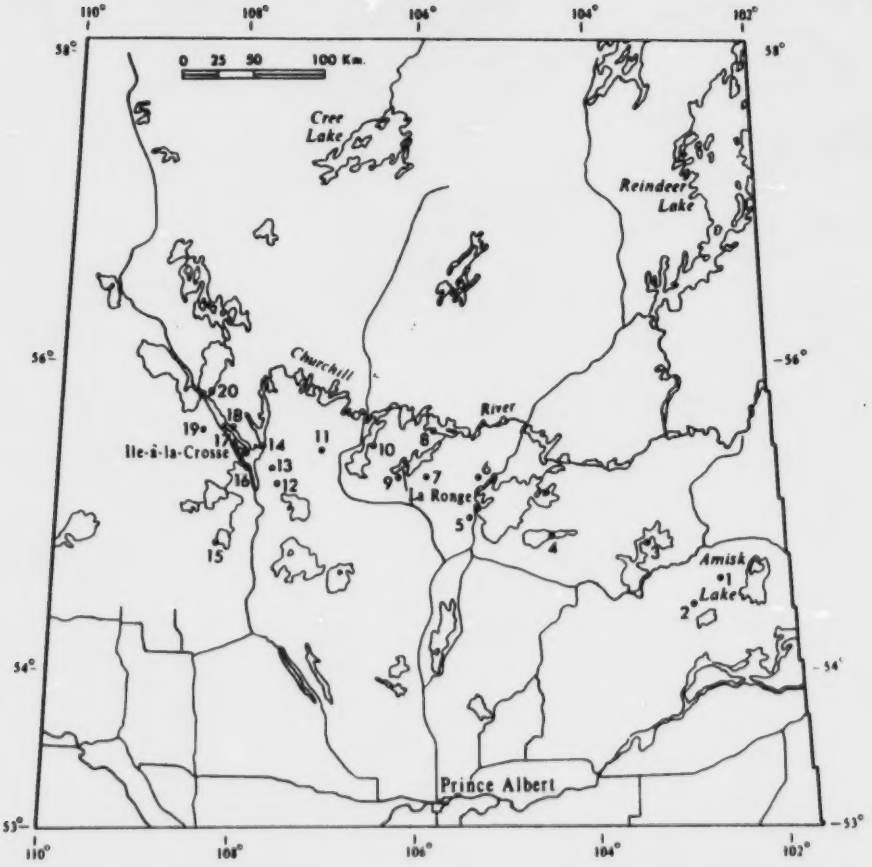
Introduction:

The purpose of this study is to evaluate the heterogeneity of existing wild rice stands with respect to plant uniformity and crop yield. The growth, flowering and maturation of plants within a stand can vary considerably with some individuals coming into flower as others are ready for harvest. An understanding of the nature and causes of such inter and intrasite variation and the selection of wild rice varieties best suited to specific habitats could lead to more uniform stands and higher crop production.

Field and Laboratory Methods:

The initial field studies were conducted from July 25-29, 1984. During this period twenty study sites were established across the province ranging from Hanson Lake in the east to Churchill Lake in the west (Figure 1). At each site the density of the wild rice stand was evaluated using twenty five 0.25 m^2 quadrats placed approximately 10 m apart along transects starting about 15 m within the stand perimeter. The flowering stage of the plants within each quadrat was also assessed. Four flowering stages were used, initial, emergent, full and very full. In the inital stage the upper female florets were visible above the leaf sheath: by the



1 Hanson Lake
2 Limestone Lake
3 Deschambault Lake
4 Wapaweka Lake
5 Montreal River
6 Nemeiben Lake
7 Morning Lake
8 Black Bear Island Lake
9 Mercer River
10 Pinehouse Lake
11 Little Seymour Lake
12 Pine River
13 Beaver River
14 Lac Ile-à-la-Crosse
15 Keeley Lake
16 Canoe River
17 Rosser Bay
18 Aubichon Arm
19 Kazan Lake
20 Churchill Lake

Figure 1. Location of the sample sites

emergent stage all of the female florets had appeared. Full flowering was indicated by the appearance of some male flowers on the panicle, with the flower almost completely open by the very full stage.

Stand density and flowering stage assessments were repeated during a second period of field work conducted from August 24-27, 1984. In addition, samples of seed were gathered, oven dried and weighed. A total of 581 wild rice plants comprising 1052 stems were also collected and the following parameters measured; number of root tillers, number of stem tillers, overall stem length, length of each internode, diameter of stem at base, subapical diameter of stem, leaf width, length of leaf sheath, length of leaf blade, occurrence of prop roots at the internodes, dry weight of aerial parts, dry weight of roots, length of rachis bearing staminate flowers, length of rachis bearing pistillate flowers, and number of female florets.

Selected environmental parameters were measured at twelve points along the transects. Water depth was gauged using a graduated staff, water temperature and conductivity were measured with a YSI portable conductivity meter, and water pH was monitored with a Metrohm Herisau portable pH meter. Daily weather data for the period April 1 to September 30, 1984 were obtained for climate stations throughout northern Saskatchewan and adjacent areas in Alberta and Manitoba. Cumulative growing degree days above a base temperature of $5^{o}C$ for the frost free period have been mapped.

Results:

(i) Stand characteristics.

The density of the wild rice stands and the number of plants in flower is given in Figure 2. Stand density was highest at Rosser Bay with stem counts averaging 133 m^{-2}. Densities were similarly high at Lac Ile-a-la-Crosse (119 stems m^{-2}) and Keeley Lake (113 stems m^{-2}) in the west, at Morning Lake (117 stems m^{-2}) in the central region and at Limestone Lake (118 stems m^{-2}) in the east. The stand at Beaver River was the most open with only 37 stems m^{-2}. Low counts were also recorded at Pinehouse Lake (47 stems m^{-2}), Pine River (45 stems m^{-2}), Canoe River (41 stems m^{-2}) and Churchill Lake (46 stems m^{-2}). The total number of stems in flower was highest in the eastern part of the province. At Limestone Lake this averaged 97 m^{-2}, with 76 m^{-2} recorded at Hanson Lake and 73 m^{-2} recorded at Deschambault Lake. Average flowering counts were considerably lower in the western part of the province with only 5 flowering stems m^{-2} recorded at Beaver River: at Aubichon Arm the count was 11 m^{-2}, at Kazan Lake 10 m^{-2}, and at Churchill Lake 9 m^{-2}.

The percentage of stems in each of the four stages of flowering at the end of July is presented in Figure 3. Flowering was most advanced in the eastern sites with over 40% of the stems at Limestone Lake already in the very full stage. For the eastern sites (sites 1 - 4) the average percentage of stems in each of the flowering categories was 16.4% initial, 11.8% emergent, 16.7% full and 27.7% very full. In the central region (sites 6 - 11) flowering was a little later: average flowering performance

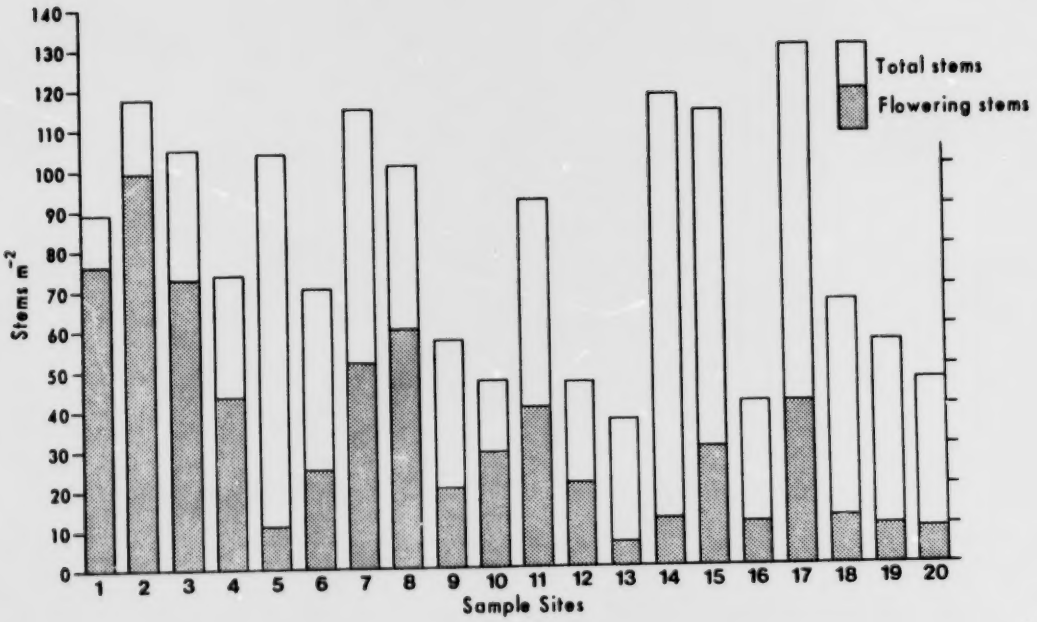


Figure 2. Stand density and number of stems in flower - July

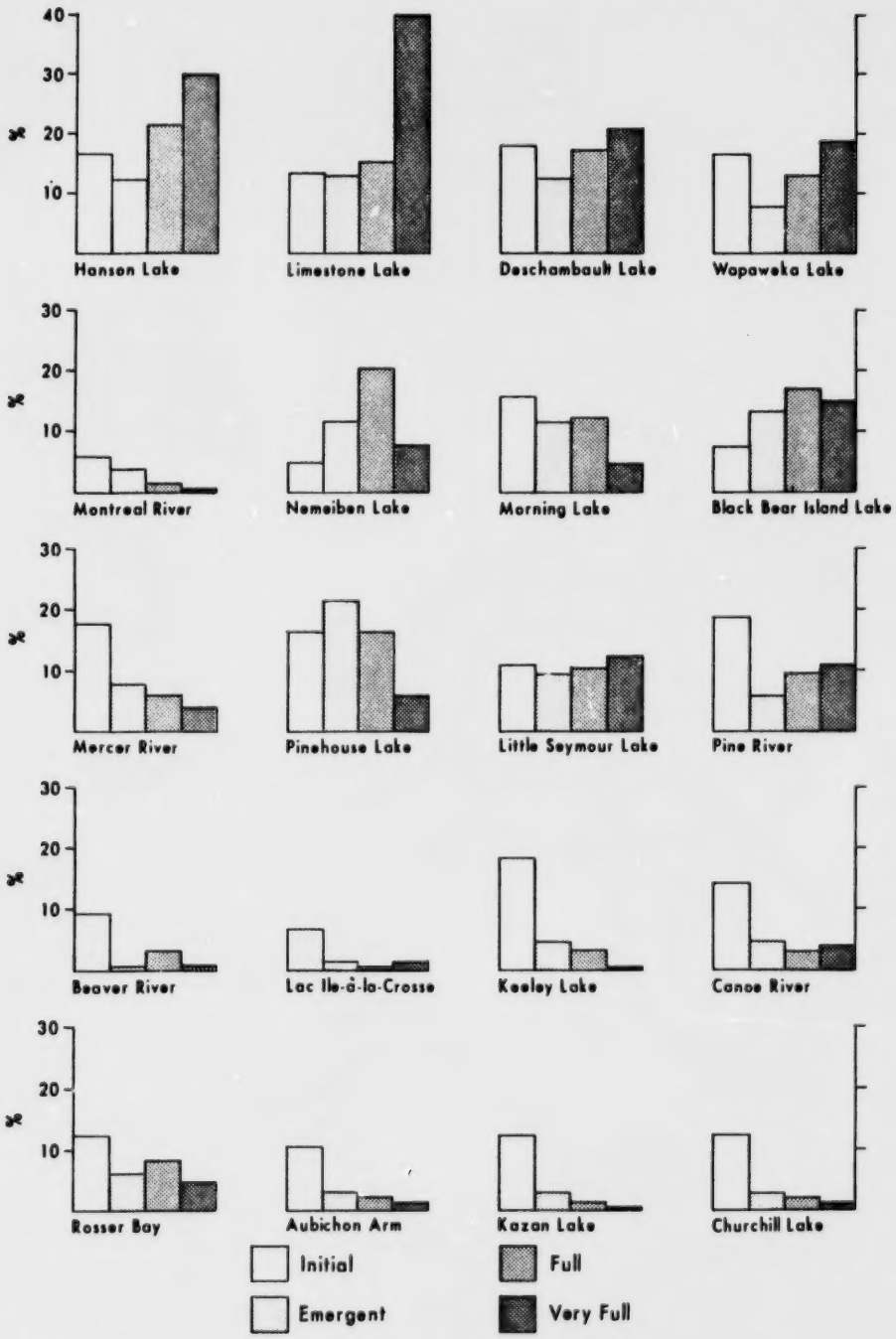


Figure 3. Percentage of stems in each stage of flowering - July

here was 12.2% initial, 12.5% emergent, 13.9% full, 8.3% very full. In the west (sites 12 - 20) the majority of the plants were still in the early stages of flowering, the group averages being 13.1% initial, 3.4% emergent, 3.6% full with only 2.8% in the very full stage. The Montreal River site was unusually late compared to adjacent sites with corresponding flower counts of 5.2% initial, 3.2% emergent, 1.2% full and 0.5% very full.

Stand densities at the end of August are shown in Figure 4; these ranged from 57 stems m^{-2} at Pine River to 207 stems m^{-2} at Morning Lake. At all sites the density of the wild rice stands had increased as a result of tillering or through the elongation of shorter stems above water level. The percentage increase in stand density between July and August is shown in Figure 5 and ranged from 3% at Lac-Isle-a-la-Crosse to 116% at Nemeiben Lake with large increases also recorded at Mercer Lake, Pinehouse Lake and Beaver River.

Flowering data for August are presented in Figure 6. Despite the significant increase in stand density during August, the overall flowering rate was very close to 100% at all sites. The highest percentage of stems in the very full stage of flowering was recorded at Limestone Lake (98.0%) with 96.8% recorded at Morning Lake and 96.1% at Deschambault Lake. Conversely, the lowest percentage was recorded at Montreal River (81.3%) with Nemeiben Lake, Aubichon Arm, Kazan Lake and Churchill Lake generally later than the other sites. Nemeiben Lake had the highest number of stems still in the initial stage of flowering (6.8%).

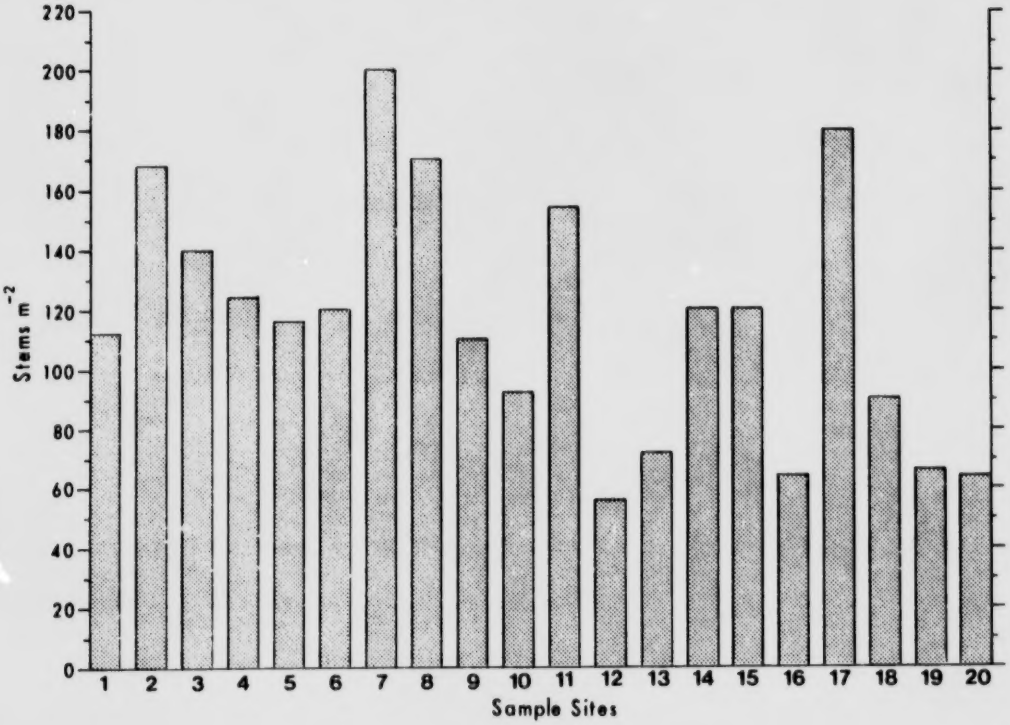


Figure 4. Stand density - August

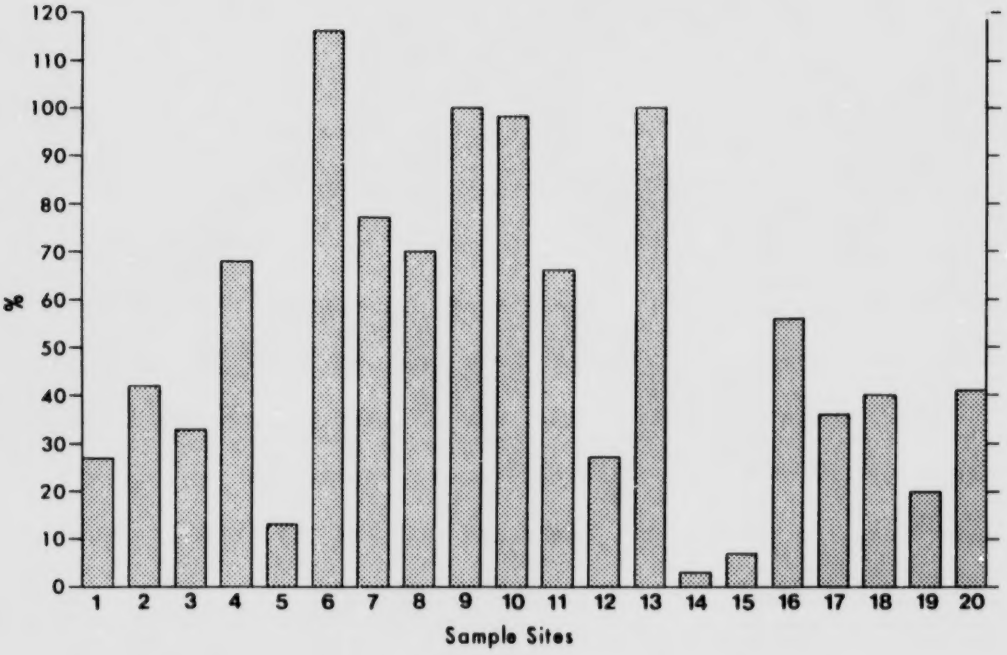


Figure 5. Percentage increase in stand density (July to August)

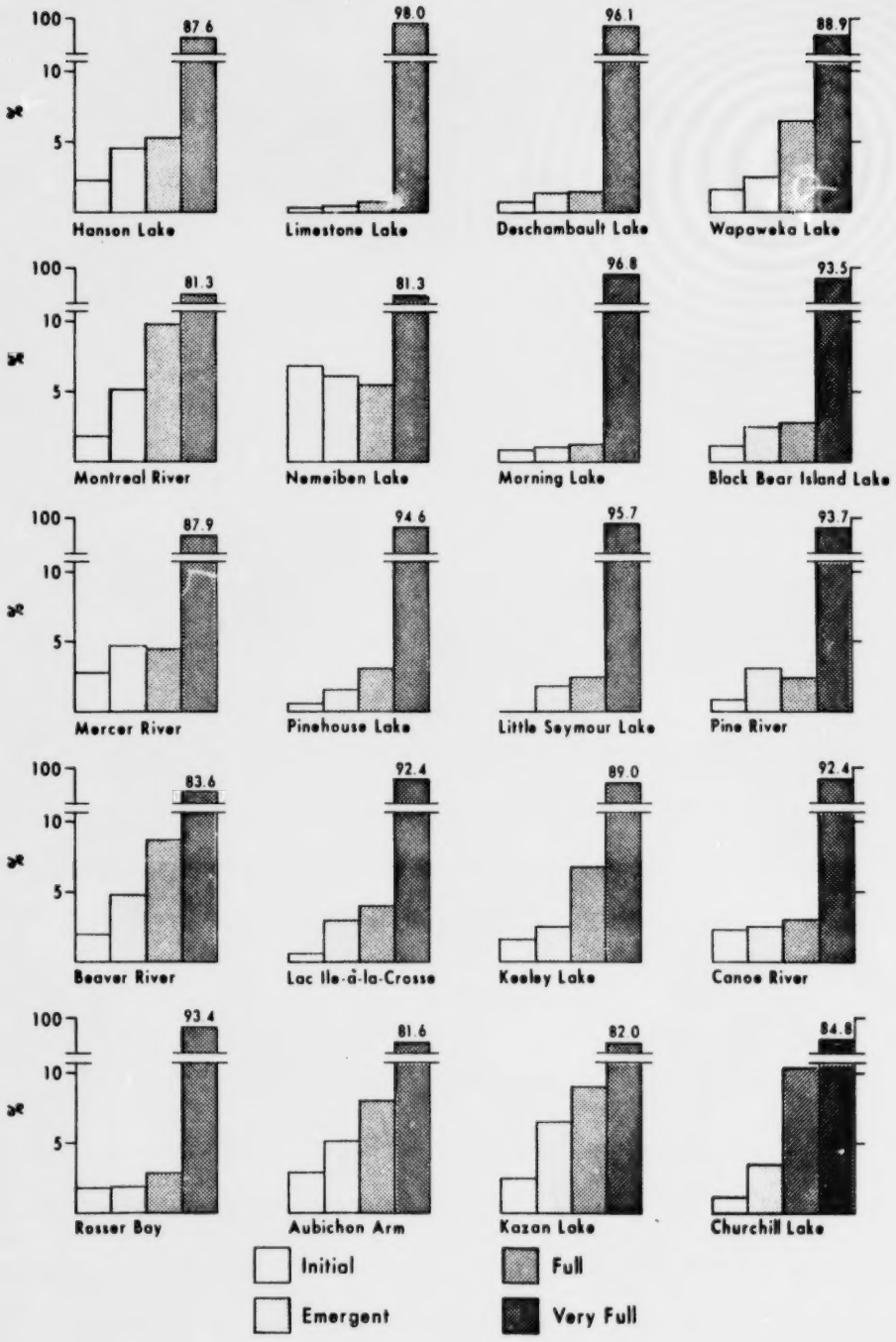


Figure 6. Percentage of stems in each stage of flowering - August

(ii) Plant characteristics.

The structure of the wild rice plants varied noticeably with respect to the number of root and stem tillers arising from the primary stem. The percentage of the stands comprised of primary stems, root tillers and stem tillers is shown in Figure 7. At Morning Lake 97% of the plants consisted of single stems, the remaining 3% composed largely of root tillers. Similarly, over 94% of the stands at Limestone Lake and Rosser Bay was accounted for by single stemmed plants. However, at Kazan Lake the majority of the stems (79%) arose from root tillers; this was also the case at Churchill Lake (75%), Beaver River (68%) and Little Seymour Lake (51%). At the remaining sites the primary shoots comprised the highest percentage of the stand, but whereas in the eastern part of the study region these were generally supplemented by stem tillers, in the west, root tillers were more abundant. The maximum number of stem tillers per plant was 3 and was recorded at Little Seymour Lake, Beaver River, Keeley Lake and Kazan Lake. As many as 11 root tillers were found on individual plants at Churchill Lake and up to 10 root tillers were found on plants at Kazan Lake.

The average height of the plant stems can be seen in Figure 8, together with the average length of the internodes and flower heads. If the height above the root crown at which the stem tillers arose is included, the tallest plants were found at Wapaweka Lake (232 cm), Hanson Lake (229 cm) and Deschambault Lake (213 cm). However, stem tillers were poorly developed at Kazan Lake (114 cm), Montreal River (127 cm) and

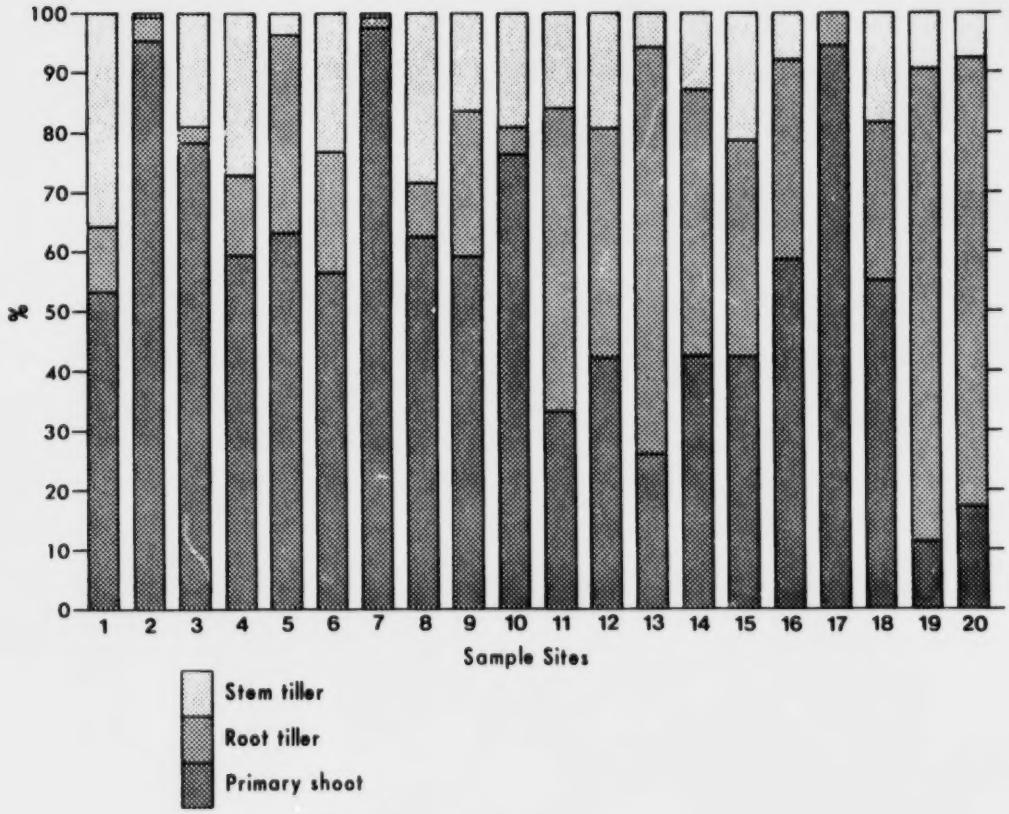


Figure 7. Importance of tillering in stand composition

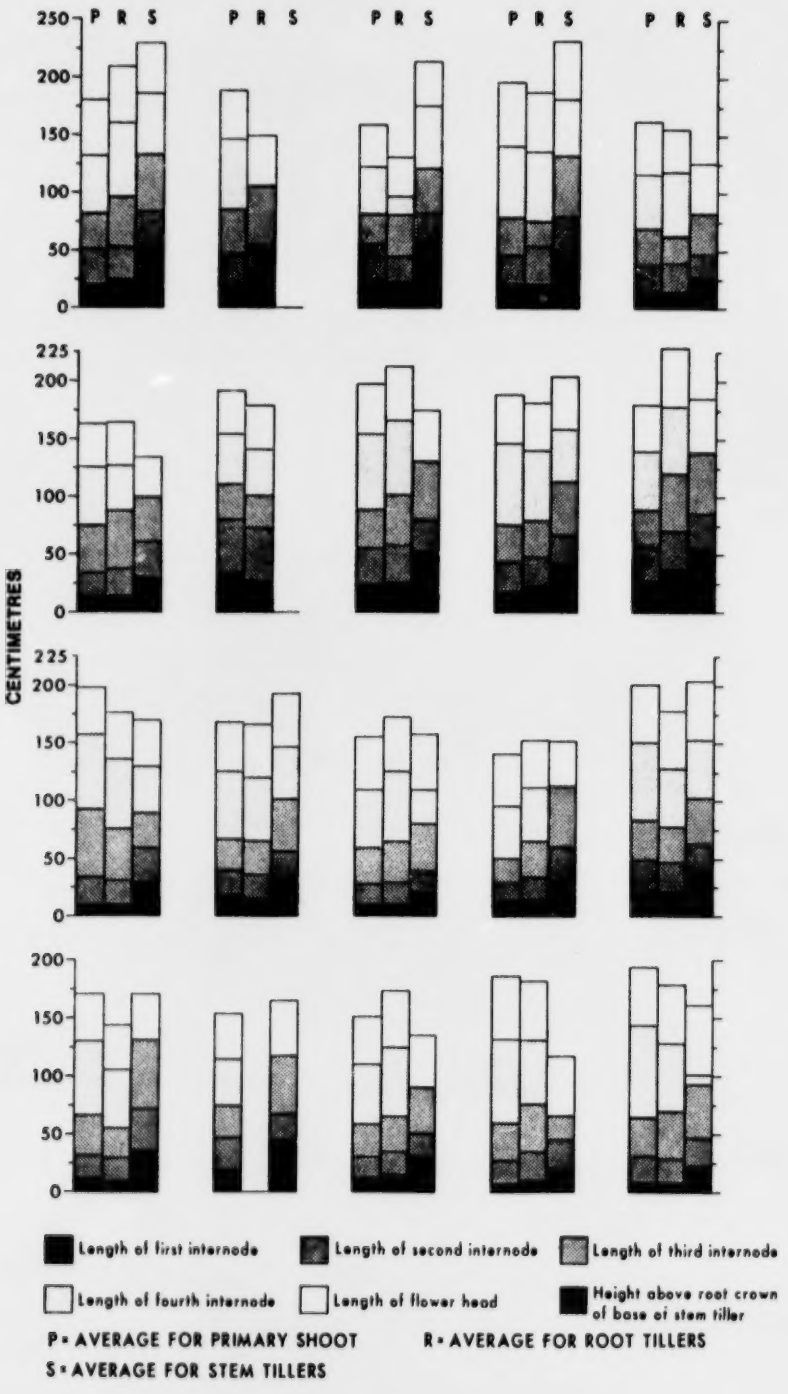

P R S
CENTIMETRES
Length of first internode
Length of second internode
Length of third internode
Length of fourth internode
Length of flower head
Height above root crown of base of stem tiller
P = AVERAGE FOR PRIMARY SHOOT
R = AVERAGE FOR ROOT TILLERS
S = AVERAGE FOR STEM TILLERS

Figure 8. Stem and internode lengths

Aubichon Arm (132 cm). The longest root tillers, were found at Pinehouse Lake (228 cm), Blackbear Island Lake (214 cm) and Hanson Lake (208 cm); the shortest were found at Deschambault Lake (132 cm) and Limestone Lake (149 cm). Only at Morning Lake, Little Seymour Lake, Kazan Lake and Churchill Lake did the length of the primary stems exceed that of the root and stem tillers. Internode lengths tended to increase towards the distal end of the stems

Plants in the eastern region produced more slender stems than those in the west. Basal diameters of the primary stems were generally the largest and ranged from 2.2 mm at Morning Lake to 9.5 mm at Kazan Lake. These same sites also had the smallest and largest root tillers with basal diameters of 1.6 and 7.4 mm respectively. At any site the stem tillers generally produced the thinnest stems, with basal diameters ranging from 2.6 mm at Little Seymour Lake to 5.7 mm at Aubichon Arm. Diameters at the subapical end of the stems were less variable. For primary stems this ranged from 1.6 mm at Morning Lake to 3.8 mm at Kazan Lake and for root tillers from 0.9 mm at Morning Lake to 3.5 mm at Aubichon Arm. At four sites the stem tillers were thicker at their subapical ends than the other stems: this was most pronounced at Rosser Bay, but even here the difference was only 0.5 mm.

The overall length of the leaves at a site was similar for all stem types. The shortest leaves were found at Nemeiben Lake and Morning Lake where they averaged 62 and 66 cm respectively. Leaf length tended to increase towards the west; at Kazan Lake they averaged 93 cm in length.

However, the longest leaves were those on the root tillers at Pinehouse Lake with a length of 96 cm. Typically, over half of the leaf consisted of a sheath still encircling the stem: on average this ranged in length from 37 cm (Nemeiben Lake) to 50 cm (Wapaweka Lake). Leaf width, measured at the base of the blade, increased noticeably in the west. At Kazan Lake the leaves on the primary stems averaged 19 mm in width. The narrowest leaves, only 5 mm wide, were found on the root tillers at Morning Lake. At several lakes the leaves on the root tillers were wider than those on the main stems; this was most apparent at Pinehouse Lake. At Deschambault Lake and Pine River the widest leaves were produced by the stem tillers.

The proportion of plants which had developed prop roots at various internodes is shown in Figure 9. When present, the prop roots generally arose from the first internode or from both the first and second internodes. Nowhere were plants found which had developed prop roots only at the second internode. A small number of plants were found at Pinehouse Lake (3.2%) and Pine River (4.2%) which had developed prop roots at the first, second, and third internodes. At eleven sites over 50% of the plants had not produced prop roots. Even though the plants from Kazan Lake were the biggest collected at any site, none of them had developed prop roots.

The overall size of the plants can be assessed from their weight. Oven dry shoot weights and oven dry root weights are presented in Figure 10. The biggest plants were found at Kazan Lake and Churchill Lake with average shoot weights of 42.2 g and 25.2 g respectively; corresponding

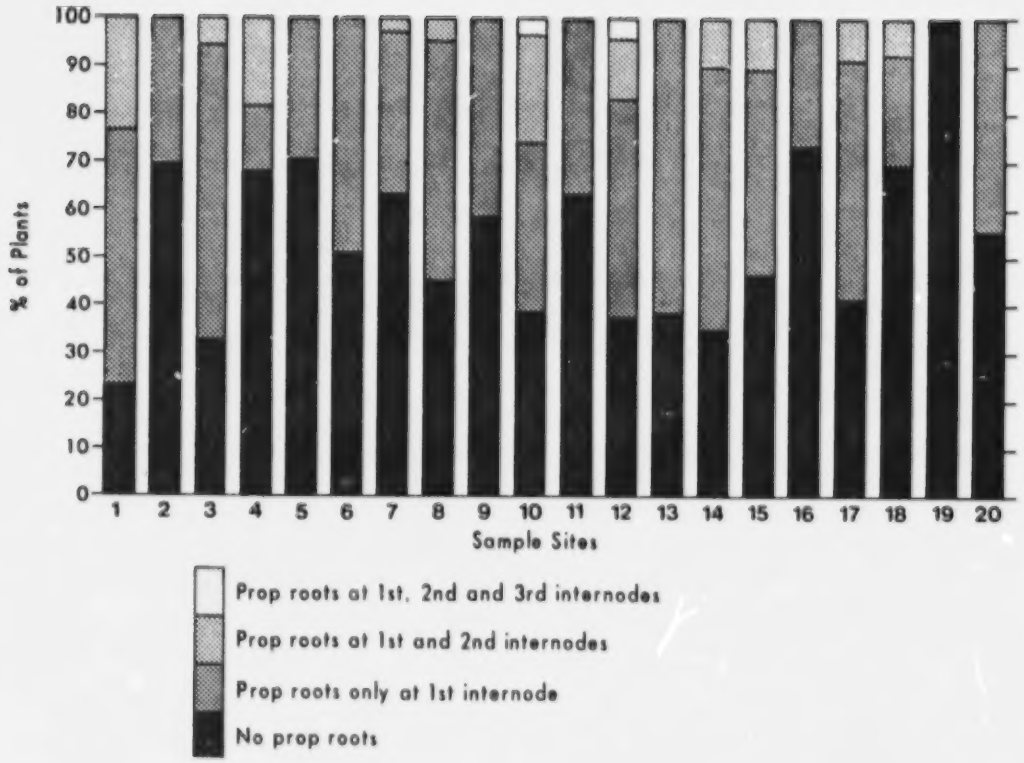


Figure 9. Prop root development

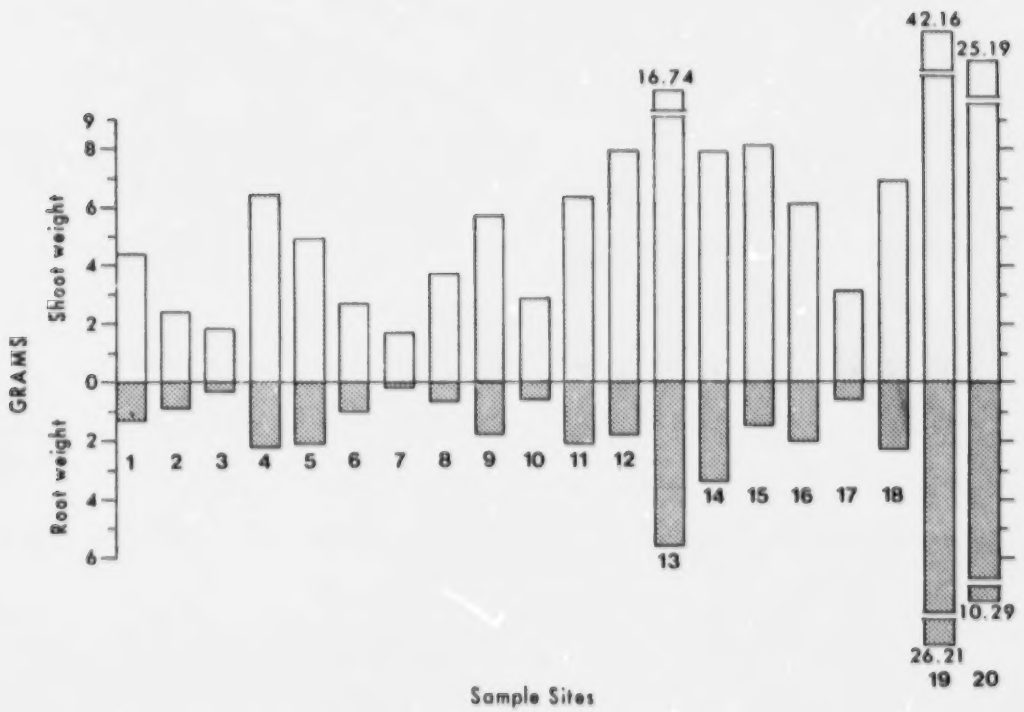


Figure 10. Root and stem weights

root weights were 26.2 g and 10.3 g. Plants from Beaver River were also comparatively large. Average shoot weight at this site was 16.7 g with a root weight of 5.6 g. Plants in the western region were generally larger than those from the eastern and central regions where shoot weights were typically less than 5.0 g. The smallest plants, with average shoot weights of 1.7 g, were found at Morning Lake. Apart from the bulky root masses previously noted for Kazan Lake, Churchill Lake, and Beaver River, average root weights throughout the study region were fairly similar averaging 1.4 g, although plants with a higher shoot mass typically possessed more extensive root systems.

Figure 11 shows the average number of seeds per site. These data were based on the number of female florets on each stem type. In general, the number of seeds produced by a root tiller was slightly higher than that produced by the primary stems. This was most noticeable at Black Bear Island Lake and Pinehouse Lake where average seed production for the primary stems, root tillers and stem tillers was 28, 45, and 29 seeds and 32, 53, and 47 seeds respectively. However, seed production on stem tillers was often lower than that of the primary stem. Plants growing at Kazan Lake were the most prolific seed producers. Here the main stems averaged 107 seeds per flower head, the root tillers 102, and the stem tillers 76. Churchill Lake and Canoe River were also very productive averaging 81 and 68 seeds per head respectively. Seed production declined towards the east. The poorest seed production was recorded at Morning Lake where primary stems averaged 17 seeds per head and the root tillers only 8. At Nemeiben Lake 18 seeds were produced on average by the primary

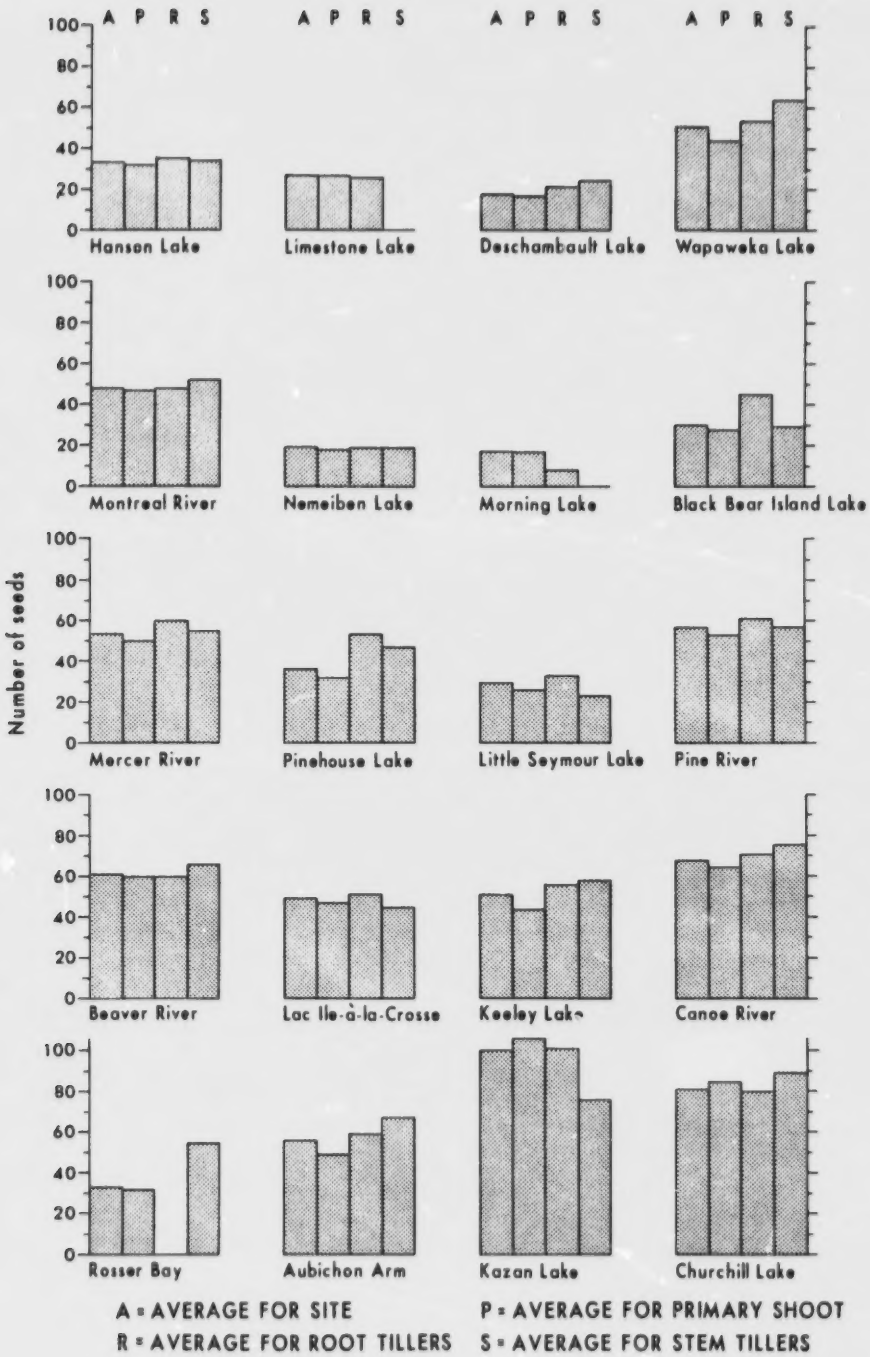


Figure 11. Number of seeds

stems with 19 seeds on both the root and stem tillers. Corresponding values for Deschambault Lake were 18, 22, and 24 seeds.

Six sub-samples of 50 seeds each were oven dried and weighed to determine the average dry weight of a seed. The results are presented in Figure 12. The heaviest seed was found at Little Seymour Lake with an average weight of 0.052 g. Hanson Lake and Black Bear Island Lake similarly produced heavy seed with average seed weights of 0.050 g. At most of the remaining sites average seed weight was in excess of 0.040 g, but at Limestone Lake unusually small seeds weighing only 0.025 g were produced.

An estimate of the potential yield of seed at each site is given in Figure 13. These data were calculated by multiplying stem density at the end of August by the number of female florets and seed weight then converting to a kg ha^{-1} basis. The most productive site was Keeley Lake with a potential yield of 3342 kg ha^{-1}. Although the sites in the west were generally the most productive, high yielding sites were found throughout the study region. At Wapaweka Lake the potential yield was 3205 kg ha^{-1}, at Montreal River 2959 kg ha^{-1}, at Mercer River 2741 kg ha^{-1}, and at Black Bear Island Lake 2734 kg ha^{-1}. The lowest yielding sites were Deschambault Lake (1133 kg ha^{-1}) and Limestone Lake (1159 kg ha^{-1}). At Deschambault Lake this results from the small number of seeds per flower head, while at Limestone Lake it reflects the light weight of the seed.

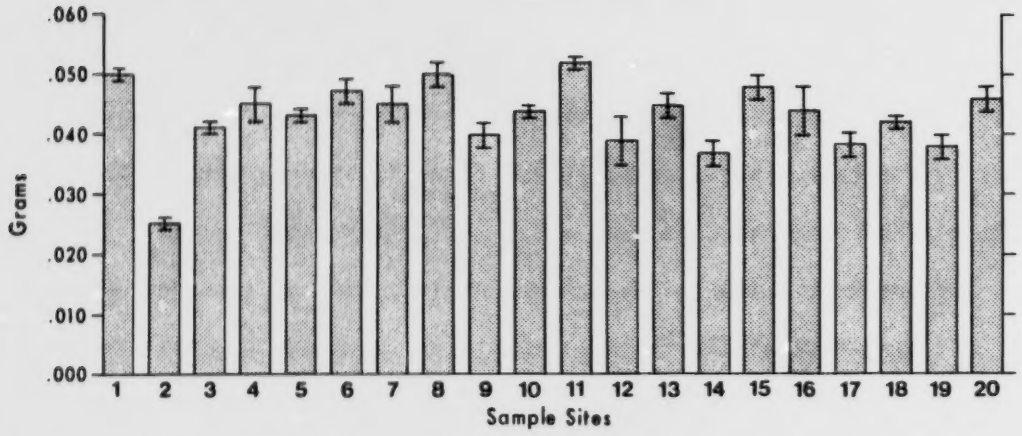


Figure 12. Seed weight

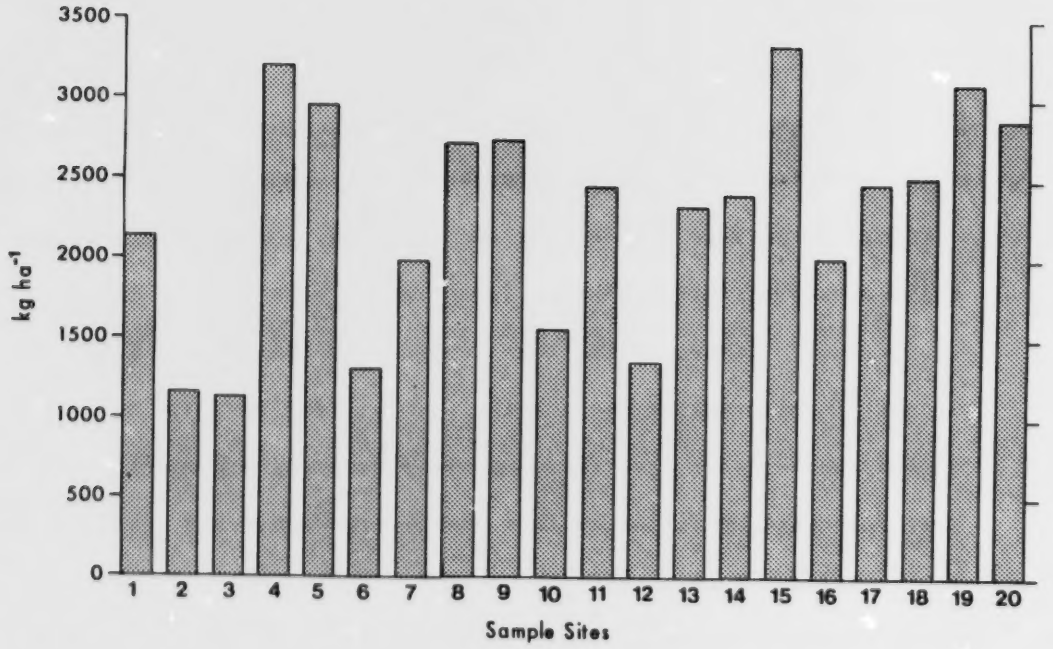


Figure 13. Potential yield

(iii) Environmental conditions.

Water temperatures averaged 24.3°C throughout the region at the end of July, although the western sites were generally cooler than those in the east. Water depth varied markedly between sites, ranging from 1.38 m at Morning Lake, to 0.50 m at Little Seymour Lake. The water was strongly alkaline in the western region: here pH averaged 8.59 but was as high as 9.28 at Churchill Lake. Approximately neutral conditions were recorded in the central region with average pH values rising to 8.24 in the east. Similarly, the conductivity of the water was lowest in the central region dropping to an average of 96 mS cm^{-1} with average readings of 126 mS cm^{-1} in the east and 149 mS cm^{-1} in the west. By late August water temperatures had cooled by 3 or 4°C, water levels had dropped at most sites, pH readings generally decreased, and conductivity readings were typically higher.

Analysis of weather data indicated that spring frosts occurred latest in the northeast part of the province, with below freezing temperatures recorded at Collins Bay as late as June 12. The first autumn frosts occurred approximately 2 weeks later in the west side of the province than in the east. Consequently, the length of the frost free season was longest in the west, exceeding 120 days at Buffalo Narrows. Cumulative growing degree days over the frost-free period are presented in Figure 14. Heat accumulation in the western and central areas was similar with 1155 units recorded both at Buffalo Narrows and La Ronge. The area to the east of La Ronge was somewhat lower at 915 units, although this increased to 1100 units in the Cumberland House - Sandy Bay district.

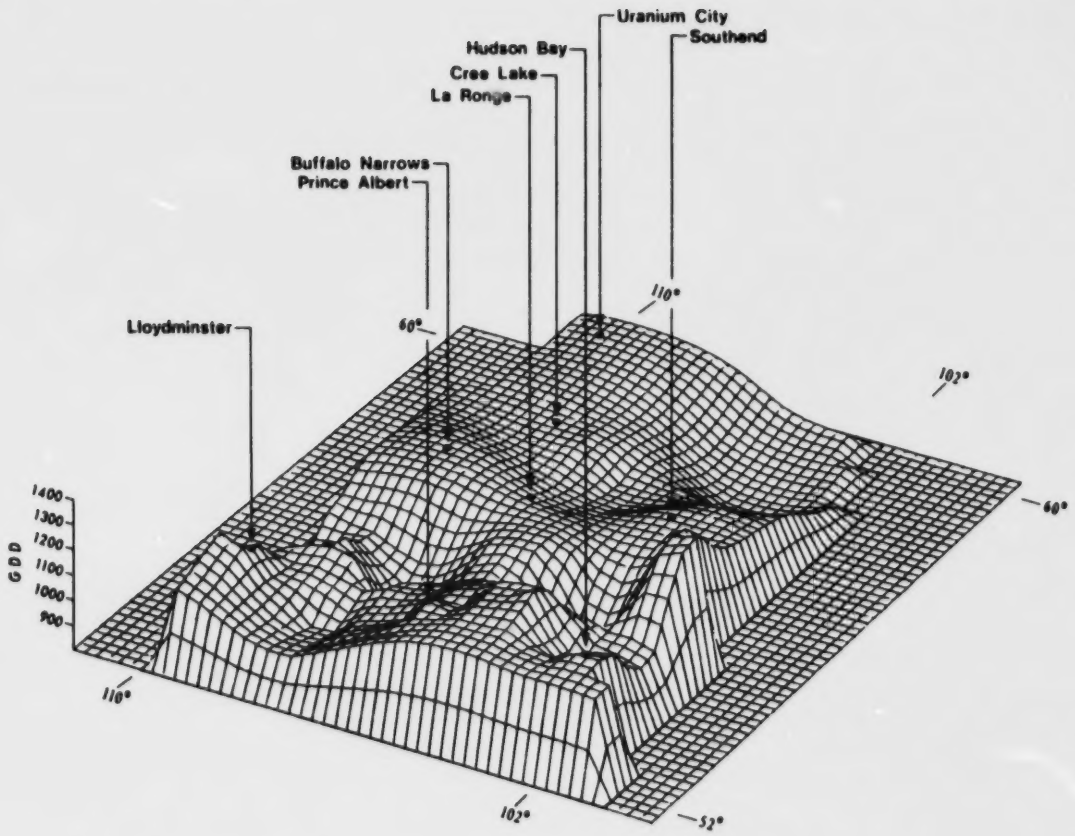


Figure 14. Cumulative growing degree days for the frost free season, 1984

Discussion:

Statistical analysis (analysis of variance) of the field data indicated that intersite variation in the total number of stems in each of the four flowering stages, was highly significant ($p < 0.001$) both in July and August. The degree of similarity between sites was established using Ward's heirarchical grouping procedure. Four major groups can be discerned for July (Figure 15). Hanson Lake, Limestone Lake, Deschambault Lake and Wapaweka Lake comprised one group characterised by advanced flowering. Nemeiben Lake, Black Bear Island Lake, and Pinehouse Lake made up a second group of moderately advanced sites. At sites such as Little Seymour Lake and Pine River, flowering was less prolific, but a good proportion was in the advanced stages. The least advanced sites included Kazan and Churchill Lakes. The August groupings for flower maturity largely reflect the percentage of each stand in the very full stage (Figure 16). The more advanced sites occur on the right of the diagram: Nemeiben Lake, with only 81.3% of the stems at the very full stage of flowering is somewhat different from the other sites because of the high percentage of stems in the initial and emergent stages.

Stem length, the lengths of the internodes and the basal and subapical stem diameters were used to provide an overall summary of intersite variation in stem characteristics. The results are given in Figure 17. Stem diameters appear to underly the major groups. For example, Kazan Lake and Churchill Lake are closely linked; both of these consisted of rather thick stemmed plants. The small diameter plants at

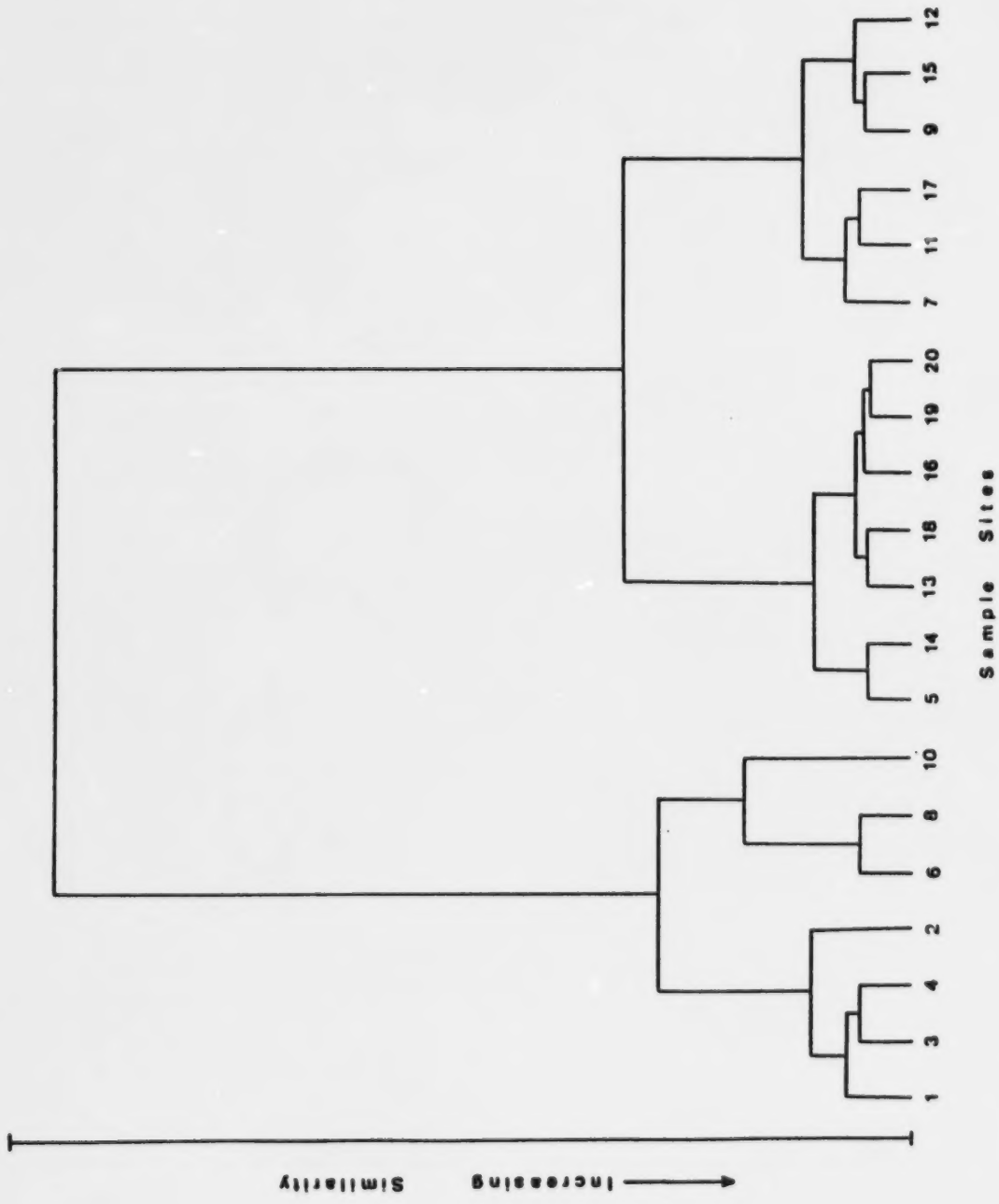


Figure 15. Site groupings based on stages of flowering - July

Figure 16. Site groupings based on stages of flowering - August

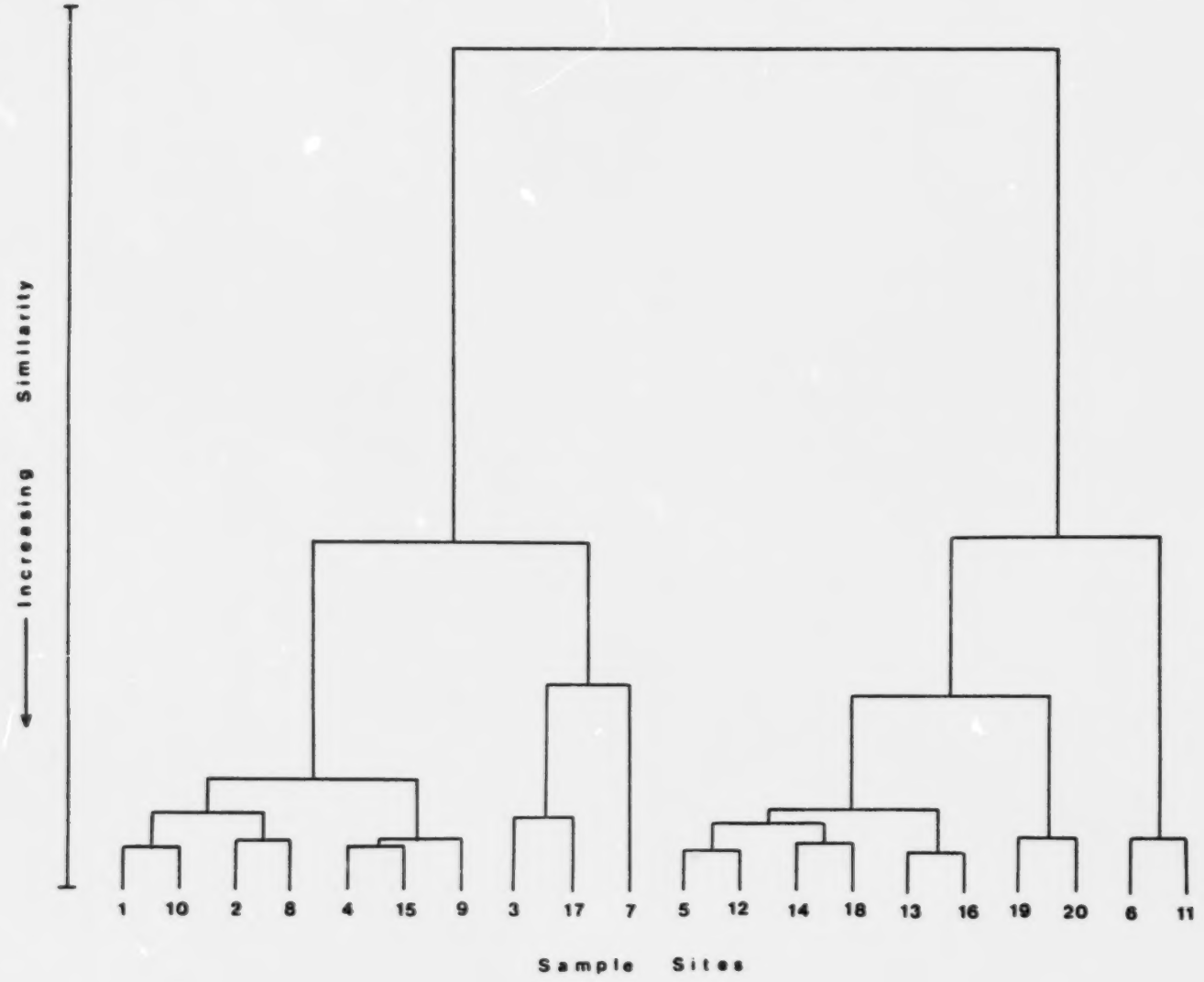


Figure 17. Site groupings based on stem length and diameter characteristics

Morning Lake form a solitary group.

The tillering capacity of the plants is shown in Figure 18. Three general groups can be seen. Beaver River and Churchill Lake, together with Little Seymour Lake and Kazan Lake comprise one group in which both root and stem tillering is prolific. Sites, such as Limestone Lake, Morning Lake and Rosser Bay, which tend to produce a few stem tillers with occasional root tillering make up a second group, while moderate tillering activity at sites such as Nemeiben Lake and Pine River form the third group.

The results of the grouping procedure for potential yield are given in Figure 19. The low yield sites include Limestone Lake, Deschambault Lake and Pine River. Sites of medium yield include Hanson Lake, Canoe River and Beaver River. The highest yielding sites were Wapaweka Lake, Keeley Lake, and Kazan Lake, with Montreal River, Black Bear Island Lake, Mercer River and Churchill Lake only slightly lower.

The interrelationships between the various plant characteristics is shown in Table 1. The height of the plant did not greatly effect its flowering and seed production capacity. However, stem diameter and leaf size were strongly linked to flower size and seed number. Root tillering was of greater significance than stem tillering in overall plant performance, and in general, the larger the plants the greater their seed production.

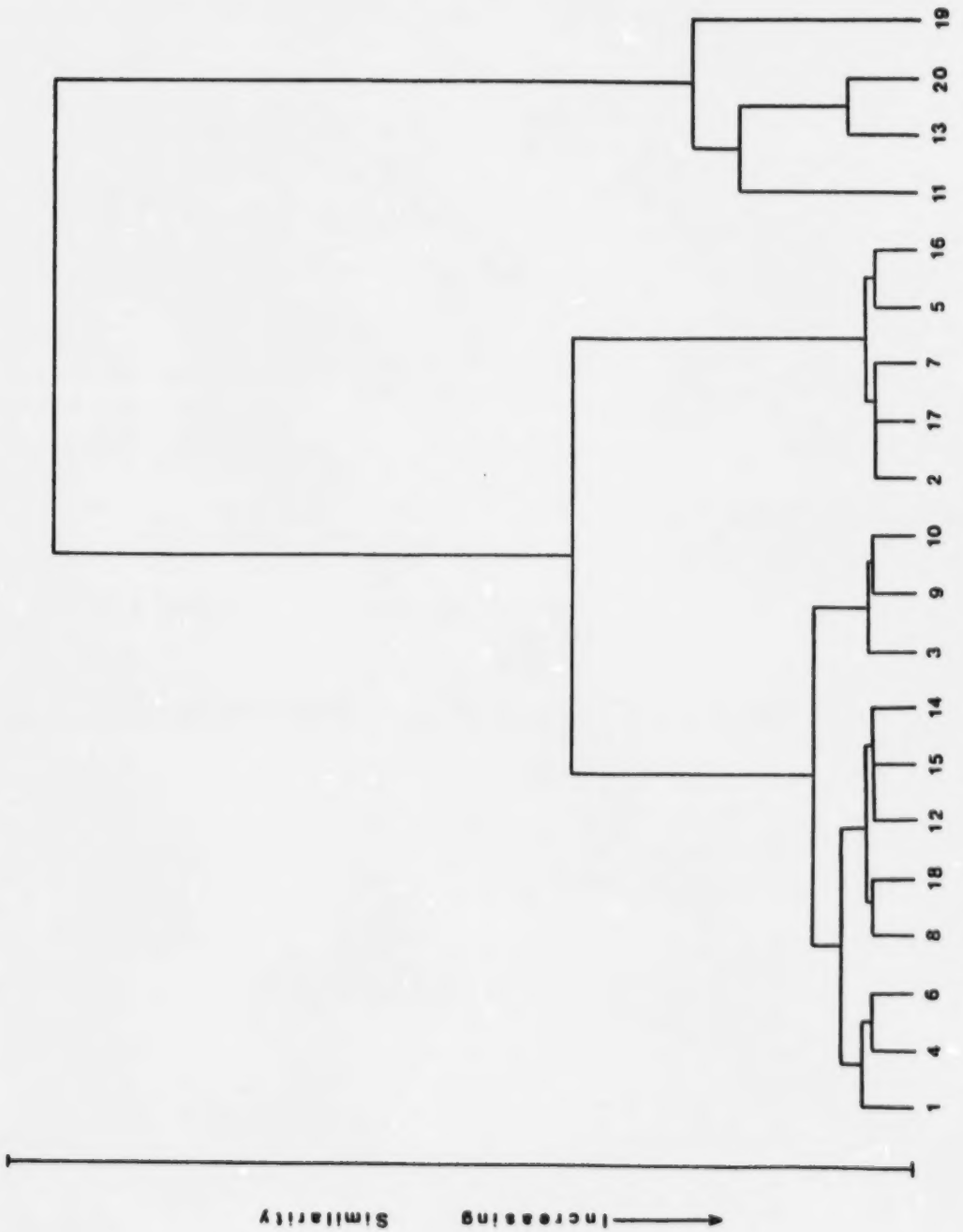


Figure 18. Site groupings based on the number of stem and root tillers

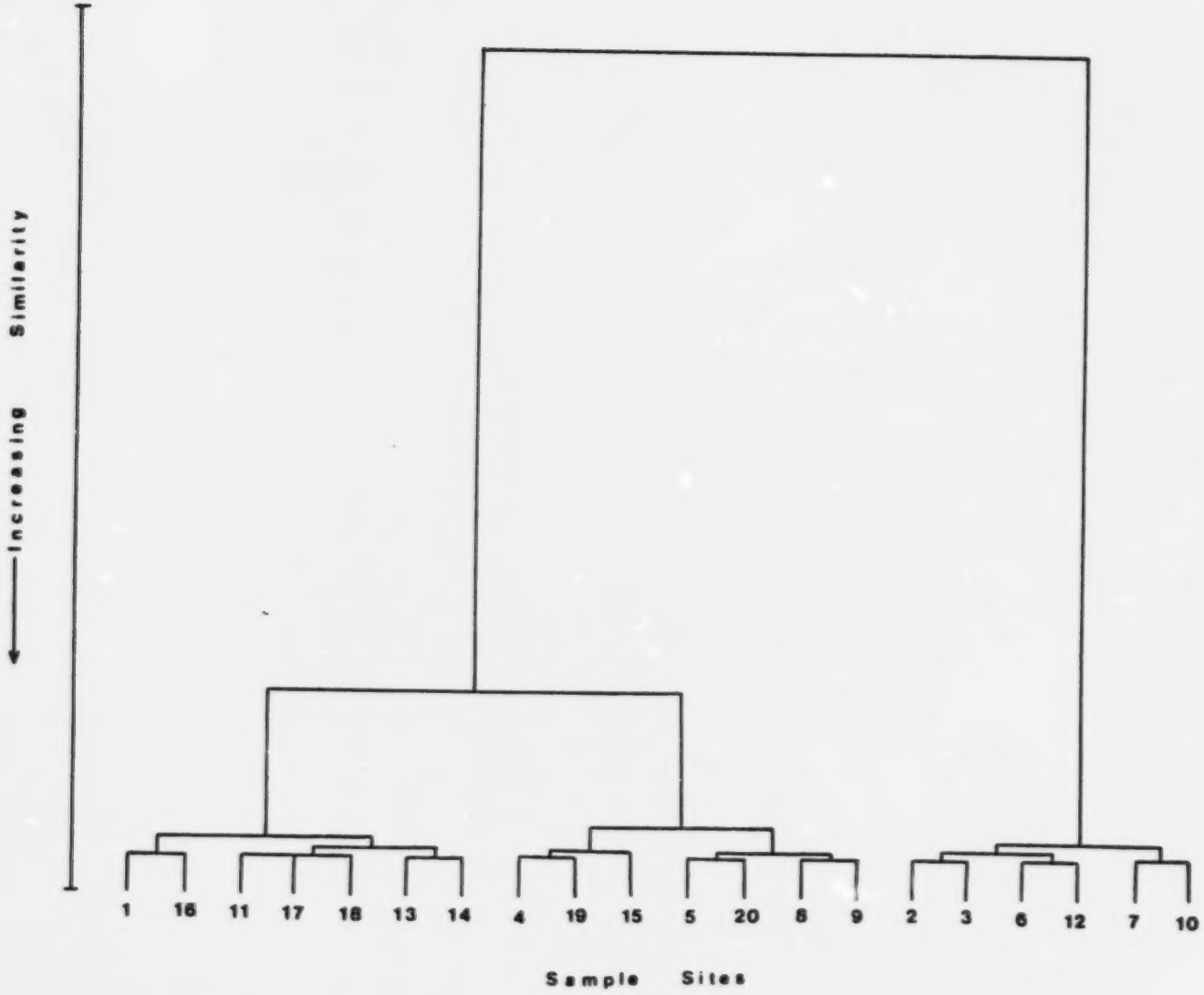


Figure 19. Site groupings based on potential yield

Table 1: Correlation coefficients between plant characteristics

	Length	Basal diam.	Subapical d.	Leaf width	Leaf length	# Root till.	# Stem till.	Root weight	Shoot weight	Pistillate l.	Staminate l.
Length	-										
Basal diam.	-0.45 *	-									
Subapical d.	- 0.23	0.94 **	-								
Leaf width	- 0.37 *	0.95 **	0.89 **	-							
Leaf length	0.10	0.67 **	0.82 **	0.67 **	-						
# Root till.	-0.44 *	0.70 **	0.63 **	0.62 **	0.46 *	-					
# Stem till.	-0.48 *	0.35	0.31	0.24	0.28	0.54 **	-				
Root weight	-0.34	0.68 **	0.66 **	0.60 **	0.51 **	0.95 **	0.51 **	-			
Shoot weight	-0.37 *	0.75 **	0.72 **	0.67 **	0.56 **	0.99 **	0.53 **	0.97 **	-		
Pistillate l.	-0.24	0.70 **	0.73 **	0.63 **	0.77 **	0.69 **	0.66 **	0.64 **	0.73 **	-	
Staminate l.	-0.24	0.42 *	0.46 *	0.37 *	0.58 **	0.21	0.15	0.17	0.27	0.54 **	-
# Seeds	-0.32	0.95 **	0.91 **	0.92 **	0.74 **	0.79 **	0.34	0.78 **	0.85 **	0.75 **	0.39 **

.....
*p<0.05
**p<0.01

The effect of individual environmental parameters on plant performance in July is shown in Table 2. A strong positive correlation existed between depth of water and the number of stems in the initial flowering stage. This suggests that the development of the wild rice plants could be delayed in deeper lakes until the stem elongates sufficiently to bring the flowering meristem above the water surface. Stands with large numbers of flowers in the emergent stage are similarly retarded. However, additional factors, including water temperature, pH, and conductivity were also significant at this later stage. In the full stage water depth and temperature were positively correlated and conductivity negatively correlated: very full flowering in July appears to be strongly promoted by higher water temperatures. Corresponding results for August are given in Table 3. The majority of the plants were in the very full stage of flowering at this time. Because of such uniformity, none of the measured parameters significantly affected plant performance at this stage of their development. Plants still in the initial stage of flowering may have been retarded at sites with higher conductivity: those at the full stage may have been adversely affected by deeper water and more alkaline conditions.

The effect of the environmental parameters on each of the measured plant characteristics is shown in Table 4. Increasing water depth produced significantly longer stems but their diameters were reduced. This, together with reduced leaf width and reduced tillering, led to an overall reduction in both root and stem weight in the deeper sites. More importantly, seed production decreased as water depth increased. Water

Table 2: Correlation coefficients between stages of flowering and environmental parameters - July

	Init	Emerg	Full	Vfull	Total
Depth	0.52 **	0.63 **	0.50 *	0.239	0.48 *
Temperature	0.18	0.40 *	0.42 *	0.67 **	0.54 **
pH	-0.06	-0.48 *	-0.36	-0.06	-0.23
Conductivity	0.08	-0.44 *	-0.50 *	-0.13	-0.27
Degree days	-0.19	0.25	0.15	-0.11	0.06

.....
*p>0.05
**p>0.01

Table 3: Correlation coefficients between stages of flowering and environmental parameters - August

	Init	Emerg	Full	Vfull	Total
Depth	-0.02	-0.27	-0.41*	0.29	0.58**
Temperature	0.33	0.05	0.04	-0.11	0.18
pH	-0.18	-0.11	0.38*	-0.17	-0.32
Conductivity	-0.44*	-0.03	0.25	0.01	-0.39*
Degree days	0.16	0.08	-0.01	-0.02	0.02

.....
*p>0.05
**p>0.01

Table 4: Correlation coefficients between plant characteristics and environmental parameters - August

	Depth	Temp	pH	Cond	GDD
Length	0.76**	-0.06	-0.18	-0.15	-0.27
Basal diam.	-0.75**	-0.20	0.58**	0.47*	0.20
Subapical d.	-0.61	-0.21	0.57**	0.44*	0.12
Leaf width	-0.71**	-0.29	0.57**	0.46*	0.22
Leaf length	-0.32	-0.17	0.63**	0.42*	-0.11
# Root till.	-0.59**	0.14	0.58**	0.43*	0.25
# Stem till.	-0.38*	0.17	0.20	0.19	-0.05
Root weight	-0.47*	0.10	0.59**	0.27	0.24
Shoot weight	-0.55**	0.16	0.60**	0.41*	0.21
Pistillate l.	-0.49*	-0.05	0.54**	0.58**	-0.07
Staminate l.	-0.22	-0.02	0.41*	0.40*	-0.32
# Seeds	-0.63**	-0.15	0.61**	0.46*	0.16
Yield	-0.32	-0.13	0.48	0.32	0.01

.....
*p>0.05
**p>0.01

temperature appeared to have no significant affect on plant form. Water pH however, was significantly related to stem thickness and leaf size. As well, root tillering was promoted by more basic conditions. Bigger plants with larger flower heads were also typical of these high pH sites, resulting in higher seed numbers per stem and larger yields. The effect of conductivity was similar to that of pH, with plant size and performance increasing in response to higher conductivity ratings. Cumulative growing degree days appeared to have no significant effect on plant growth or productivity.

Concluding Remarks:

Wild rice production is tied to two groups of factors -- the nature of the plants and the nature of the environment. As well as collecting the data mentioned above, samples of seed were collected for seeding trials in the spring of 1985. These trials are designed to see if the characteristics of the plants -- particularly seed weights and seed numbers can be maintained at sites other than those from which they were gathered. If the high yielding qualities of sites like Keeley Lake persist in other habitats, then such plants would be very suitable for seed banks for use in new seeding programmes. By carefully monitoring growing conditions and plant characteristics the first steps in a seed selection programme can be taken. This will represent an important stage in the expansion of the wild rice industry in Saskatchewan.

DEVELOPMENT OF A NEW APPROACH TO WILD RICE HARVESTING IN NORTHERN SASKATCHEWAN

BY

R.L. KUSHWAHA* G.E. MILLER B.B. PLANCHOT D.E. PLETZ

I. THE NEW APPROACH

The new approach consists of a powered reel operating at a suitable speed to dislodge the rice kernels without injuring the plants and collecting the falling rice. Although this approach is new for wild rice grown in northern Saskatchewan in lakes, however, it has been used for domesticated rice grown in Minnesota (Schertz et al. 1978) during early years of production for multi-pass harvesting. The design includes a powered reel, rice-catching troughs and an auger assembled on a 3.05 m wide existing bucket supported on pontoons. Light aluminum tubing and aluminum sheet metal was used in fabrication to keep the weight to a minimum.

II. MAJOR COMPONENTS

The complete harvester unit has the following main components:

a) Floatation device (two pontoons).
b) Central frame, deck and attachment links.
c) Header and reel assembly.

1. Floatation device (pontoons).

A flat bottom hull 4.9 m long was designed including a tunnell action feature to increase planing ability at low

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* R.L. Kushwaha, a Research Scientist from the Agricultural Engineering Department, University of Saskatchewan, is the Senior Project Researcher. This paper is condensed from the original copy of the research report.

speed operation (Fig. 1 and 2). The two pontoons provided required stability and control during harvesting operation and while turning the harvester. The angle sides of the pontoons provided a surface at right angle to the resultant water forces aiding in stability of the unit. The line of action of the resultant force passed through the centre of gravity of the harvester to prevent any rolling and skipping action. The pontoons fabricated from aluminum sheet metal were filled with marine slab foam.

2. Central frame, deck and attachment links:

The central frame formed a deck of 1.52 m wide by 2.44 mm long. The deck supported a 1600 cc aircooled VW engine with 1.37 m propeller, operator seat and controls. The front of the deck had attachment for the header unit and mechanism to raise and lower it. The deck level was 610 mm above the pontoon which provided sufficient clearance for the rice plants. (Fig. 1, 2, 3 and 4).

3. Header and reel assembly:

A 3.05 m wide collecting bucket was used as a header (Fig. 1, 2, 3 and 4). It was equipped with 100 mm wide, 600 mm long and 60 mm deep rice collecting trays spaced at 75 mm apart. (Fig. 3). The trays were pointed at the front to permit the rice stalks to divide and pass between the trays.

The reel with one metre diameter was fabricated with five-bats. (Fig. 2). In order to minimize wrapping of stalks, the area between the centre and the bats was covered with a 13 mm square wire mesh. Rubber belting flaps were added to bats for gentle impact to rice heads.

The reel mechanism was designed to operate at a travel speed of 12 km/h (7.5 mph). In order to impart a gentle impact to rice heads, the reel index of 1.25 was proposed.

III. FIELD TESTS

The completed unit (Fig. 4) was tested for its functional evaluation during the 1984 harvesting season. The unit was operated at a speed between 7-8 km/h during rice harvesting.

Tests were conducted along with a conventional speed head harvester to compare relative harvesting efficiency. The conventional speed head harvester was operated between 16-24 km/h.

Tests were also conducted using the harvester with and without operating the reel to evaluate the effectiveness of the reel and at various reel speeds.

High speed film of harvesting action of conventional speed head and the powered reel were taken to evaluate the differences in harvesting efficiency.

In few tests, rice catching trays were replaced with an equal width of plywood piece to determine the effectiveness of the trays.

Tests were conducted in Big Stone Lake and Lac La Ronge in northern Saskatchewan.

IV. RESULTS AND DISCUSSION

The new harvester was very stable in water and walking from one side to the other did not effect buoyancy balance. This was the most important aspect of the floatation component

of the harvester from the safety view point. There were three persons on the harvester including an operator during testing.

Observations of the powered reel operation showed that it was not effective in bringing the rice heads towards the collecting trays. Increasing the reel speed by 50 percent did not improve the harvesting efficiency. Table 2 shows the summary of test results in comparison with the conventional speed head harvesting. In nearly all the tests, the harvesting efficiency of the new harvester was between 55 to 65 percent of the conventional harvester. Replacing the rice catching trays with a plywood piece improved the harvesting efficiency by 10 to 26 percent.

Although the action of reel was positive, it was not as much as anticipated. The high speed film of harvesting action with reel showed that the reel pushed the rice heads downward at the initial contact. Rice kernels dislodged at this point fell into the lake resulting in poor harvesting efficiency. On the other hand, with the conventional speed head, the rice plants bent toward the bucket and slith against its leading edge. Due to high impact to plant most of the rice fell into the bucket. Thus, the earlier concept of plants bending forward at the time of impact proved wrong. This is the reason that the harvesting efficiency of the speed head harvester was always higher.

On the basis of high speed film it appears that the efficiency of the speed head harvester is considerably higher than 20 to 25 percent which is being estimated by the operators. There are no data available on actual rice yield, however, it is estimated that the lake rice yields about 680 kg/ha (605 lb/acre). During 1984 harvest, producers have been harvesting

over 224 kg/ha (200 lb/acre), which represents harvesting efficiency of nearly 35 percent with the speed head harvesters.

Future work planned for next year includes increasing the reel diameter and redesign of front rice catching trays.

Acknowledgements

The authors acknowledge the financial support by the Saskatchewan Agricultural Research Fund Board, and Regional Extension Services Saskatchewan Agriculture for this project. Assistance and cooperation of Mr. Kaz Parada, La Ronge Industries, La Ronge, Saskatchewan and of Mr. Pab Orcajada, Wild Rice Agrologist, Saskatchewan Agriculture, Northern Agriculture Unit is gratefully acknowledged.

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TABLE I

NORTHERN SASKATCHEWAN

WILD RICE PRODUCTION

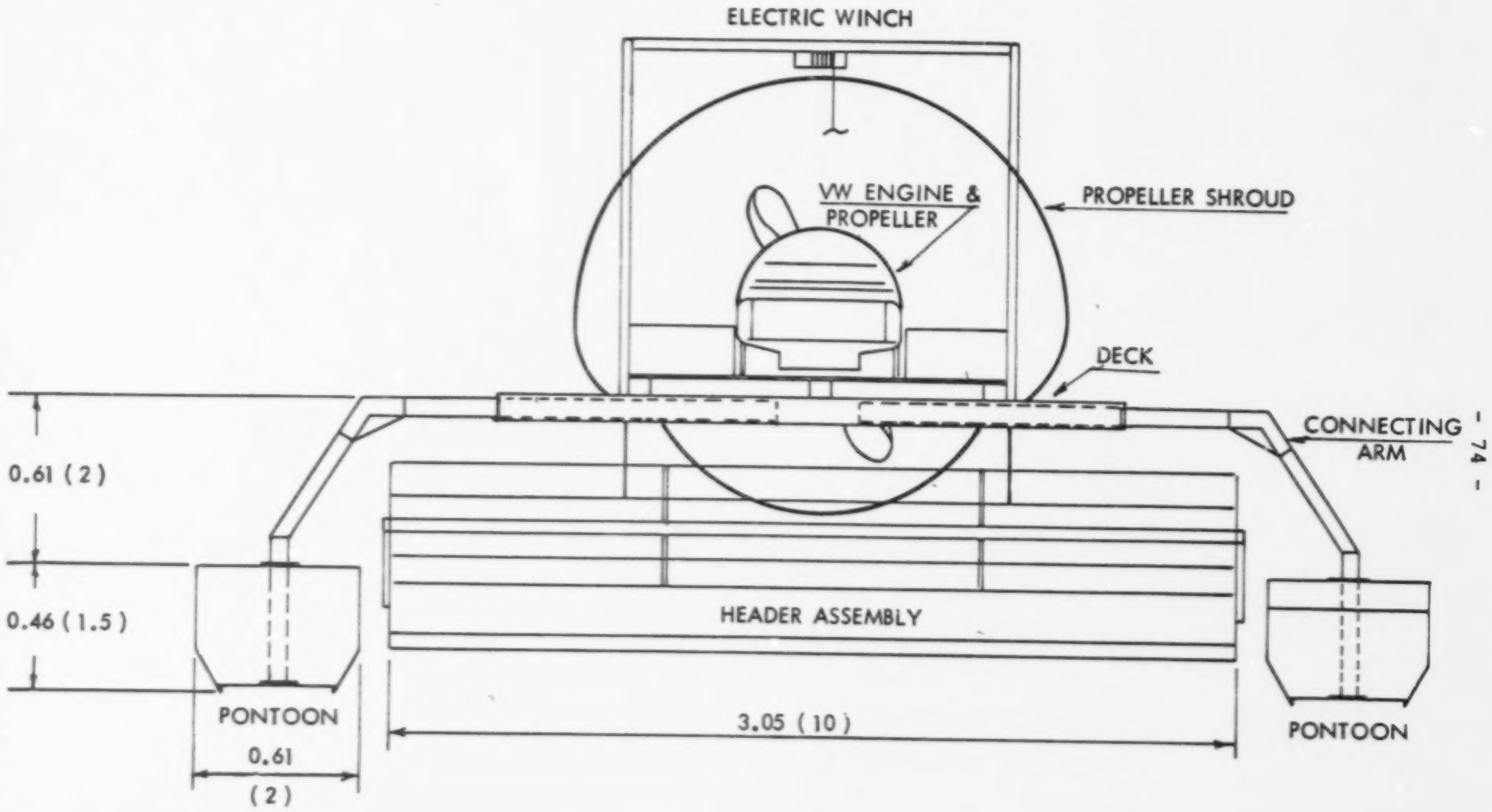
YEAR	GREEN RICE PRODUCED kg	lbs	PERCENT CHANGE
1978	27,470	60,500	-
1979	72,640	160,000	+164.4
1980	145,870	321,300	+100.8
1981	233,265	513,800	+ 59.9
1982	236,400	520,700	+ 1.3
1983	250,210	551,610	+ 5.9
1984	488,382	1,074,441	+ 95.0

TABLE II

Harvesting efficiency of the New Harvester (%)
1984 Season

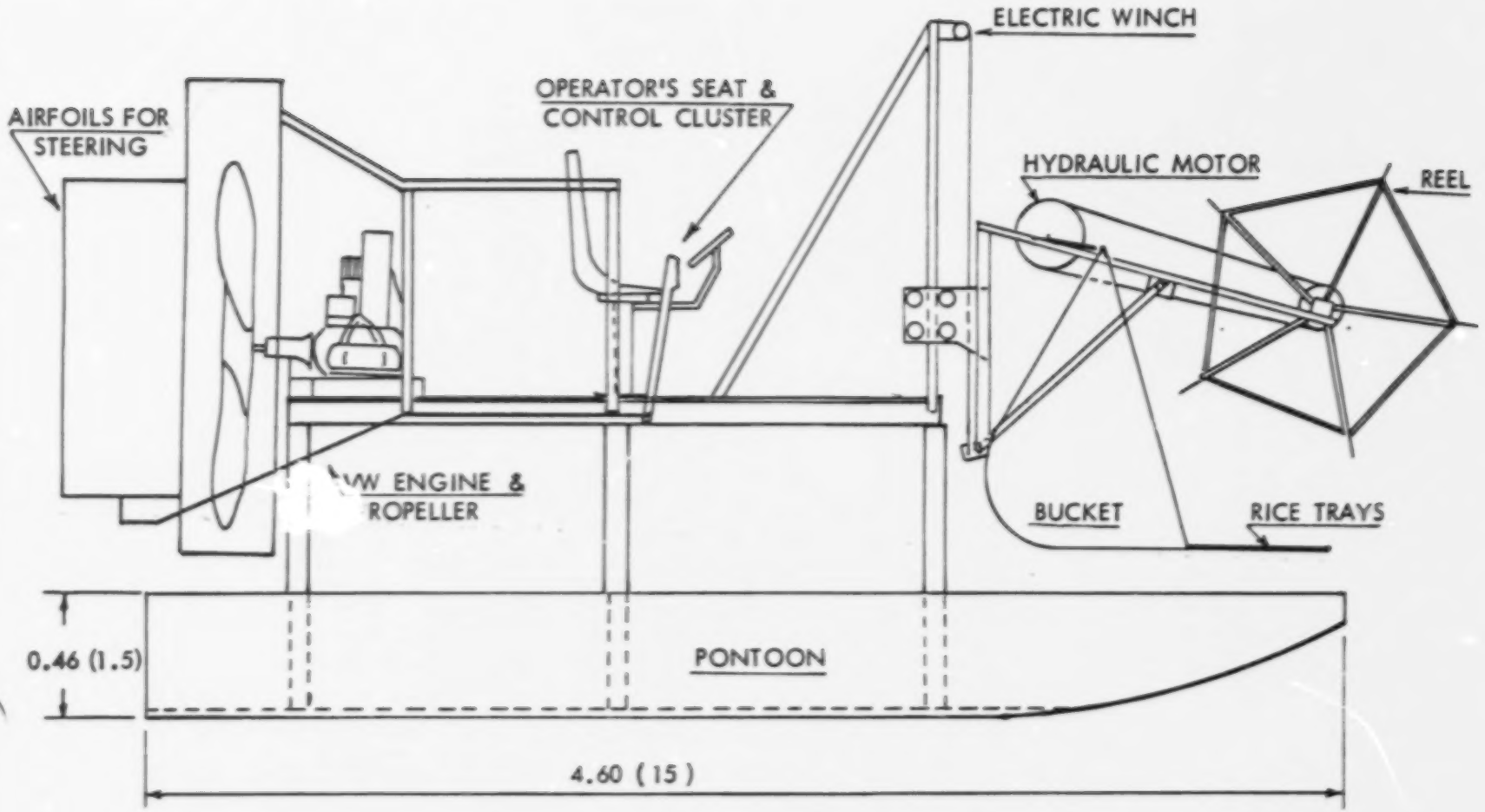
Reel Speed rpm	With Catching Trays	With Plywood Piece
0 (raised)	16*	no test
40	53	62
60	60	86

* Conventional speed head 100 percent.



SCHEMATIC FRONT VIEW OF THE NEW WILD RICE HARVESTER

Figure 1.



SCHEMATIC SIDE VIEW OF THE NEW WILD RICE HARVESTER

Figure 2.

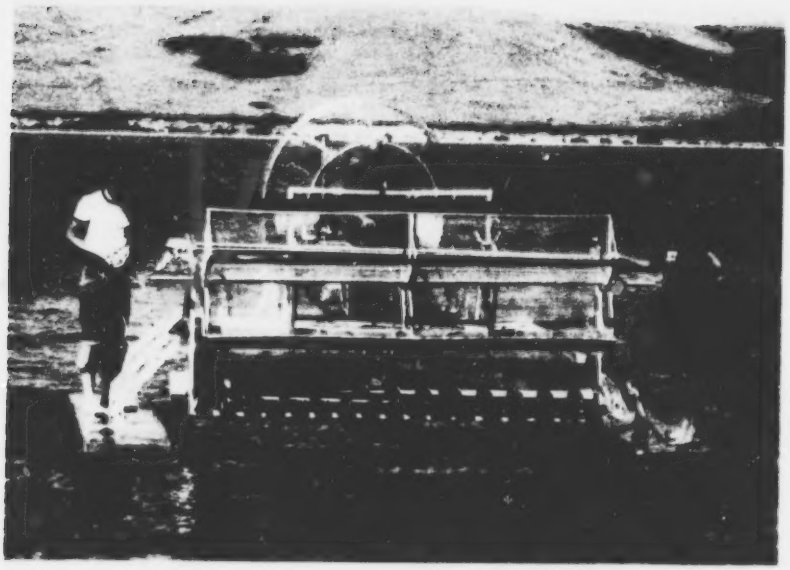


Figure 3. The complete harvester during preliminary trial

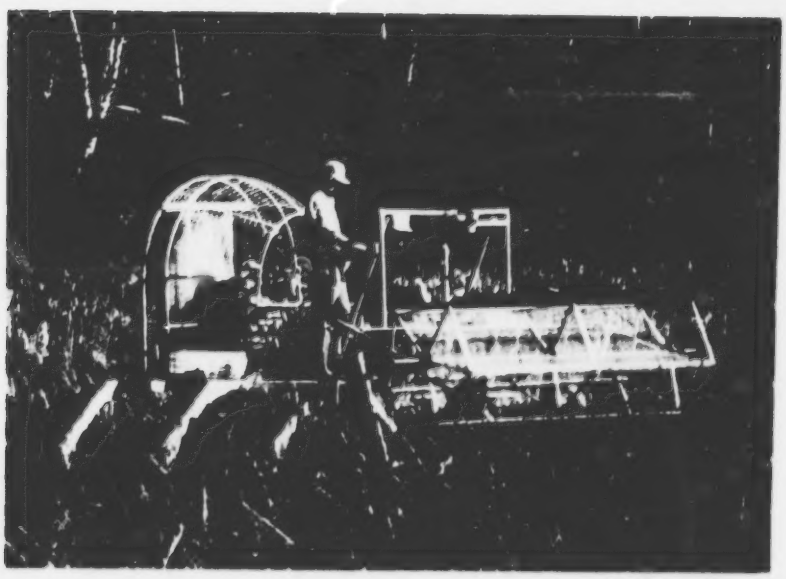


Figure 4. The harvester during field test

DEMCHENKO LAKE - APPLIED RESEARCH PROJECT*

I. BACKGROUND

Demchenko Lake was first seeded in 1966 but was not successful. Reseeding was done again in 1967 and was also unsuccessful. No more reseeding was done until 1981 when the Northern Agriculture Unit decided to use the area as its demonstration project.

Around 1,300 pounds was seeded in 1981 which almost covered the 70 acre lake. Germination was fair, but the plants gradually died or were destroyed around or during floating leaf stage. Only around 5 acres at the south end of the lake grew moderately well to maturity.

In the succeeding years, up to 1983 reseeding had been done in some sections of the lake without any success.

Early in 1984, a decision was made to undertake applied research study in the area.

II. OBJECTIVES

1. To closely monitor major variables in the growth and production of wild rice in a small muskeg type lake.

2. To determine the importance and effect of water quality, water levels, sediment type, contents and depth for the successful propagation of wild rice.

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* Fieldwork, and initial preparation of report was done by Bill Plunz, Field Worker, under the direction of Pab Orcajada, Wild Rice Agrologist, Northern Agriculture Unit, Extension Service, Department of Agriculture.

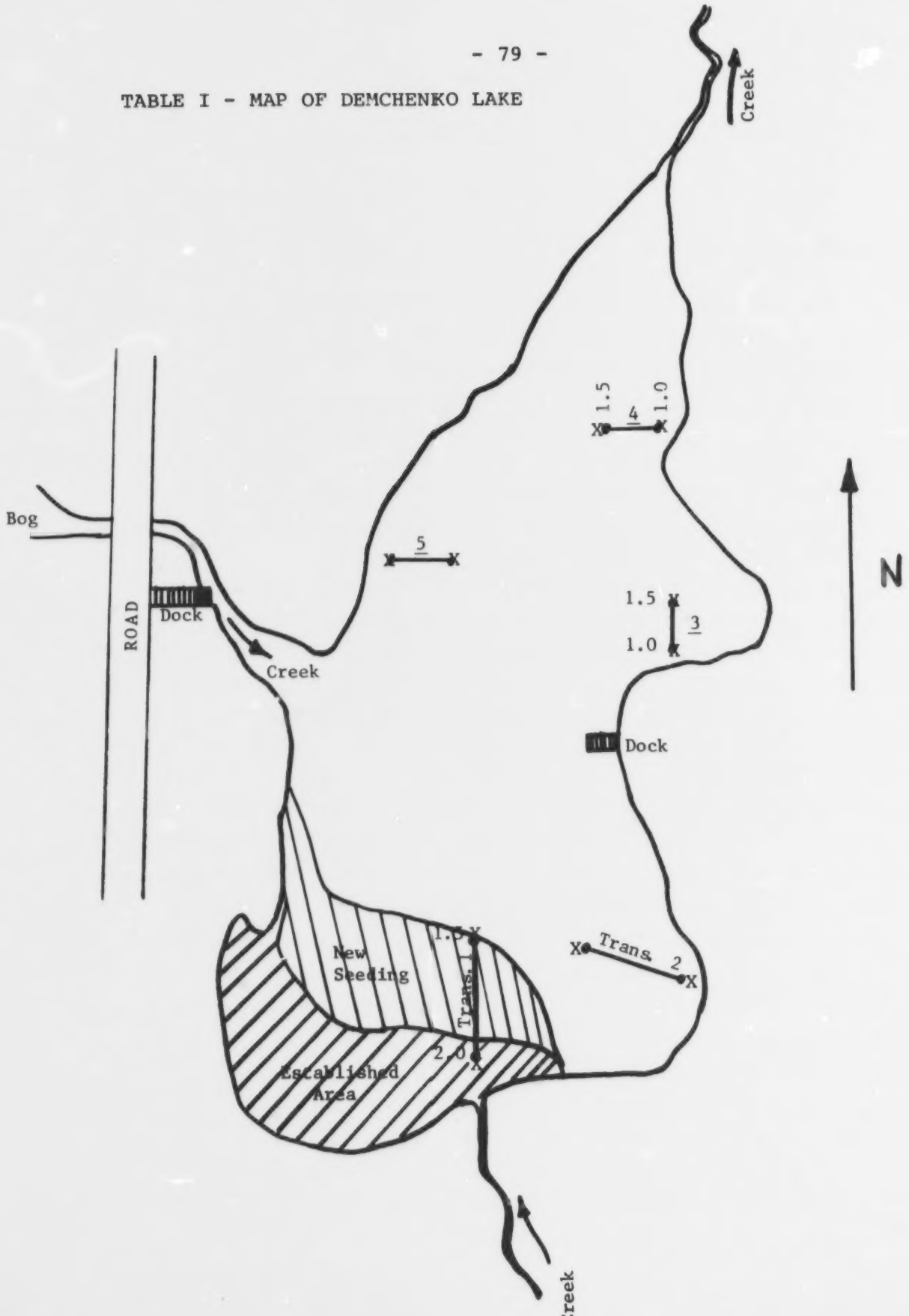
3. To apply results to practical recommendations that will assist those people growing or attempting to grow wild rice in similar water bodies.

III. METHODS

Seeds used for the project had been wintered on site at a depth of 1.5 meters. 427 kg of seed rice were broadcast over the lake at a rate of 23 kg/ha, using a cyclone, 12 V. battery operated seeder. The seeder was fitted to the bows of two canoes lashed together with poles and powered by a 4 H.P. outboard motor. Travel speed was regulated at approximately 4 km/hour. The use of marker bouys was not employed, but the operators attempted even coverage using natural land marks as guides. Seeding was completed on May 7 and May 8, 1984. Water temperature was recorded to be 5°C at seed storage site.

On May 28, 1984, five transect lines were established perpendicular to shore, each with permanent sampling stations located at 1.0 meter and 1.5 meter depths. A 0.2 meter sampling site was intended, but no sites were found suitable on the lake at this particular time. At each station, two lengths of 3.5 meter reinforcing bars were embedded in the sediment, 1 meter apart, allowing repeated placement of a 1 square meter wood frame quadrat. The transects were established to insure good representation of conditions over the entire lake. The permanent stations were visited on a weekly basis whenever possible, to monitor the progress of wild rice growth through its various growth stages. Care was taken to ensure no undue disturbance of the plants in the quadrats. Water and sediment samples were taken adjacent to the quadrats. Additional, relevant observations on wild life activity,

TABLE I - MAP OF DEMCHENKO LAKE



weather conditions, conditions near inflowing water, competing weed fauna, wind and wave action were recorded. Water depth was recorded from a permanent reference pole on the lake. Water turbidity was checked using a 20 cm white disc lowered into the water.

Water samples were taken in a composite manner at 1 meter, 1.5 meters and the mid point. Sediment samples were taken in a similar fashion to a depth of 15 cm, mixed and air dryed prior to analysis. Sediment depth was recorded by pushing a 2" x 2" wooden pole down to submission.

Twenty-five plant samples were selected just prior to harvest at random and without bias from each quadrat. Where quadrats had been predated or did not survive, plants closest to the quadrat were selected to fill the required number. Plants were then analysed for length of male and female rachis, number of seeds, subapical and basal diameter, stem and root weight, number of tillers, internode length, leaf width, length of blade and sheath, and presence of prop roots.

Water temperature and conductivity were recorded using a YSI Model 33, S-C-T meter. Dissolved oxygen was recorded using a YSI Model 51B meter calibrated to 1,200 feet above sea level. Water pH was measured using a glass electrode-type meter, calibrated to neutral solution.

IV. OBSERVATION

Stored seed was removed from the water on May 7, 1984. Water temperature of 5°C had already promoted germination, especially around the extremities of the bag to a depth of 5 cm. Some seeds displayed primary root development to a

length of 3 cm, causing an entangled mass that made seeding with the cyclone seeder relatively impossible. Seeding in this manner caused extensive damage to the seed that would certainly make it unviable. Hand seeding of the "clumpy" mass was slightly more successful but still resulted in damage. Fortunately the inner most portion of each bag showed little or no sign of germination. This phenomenon has been theorized to be caused by the high concentration of chemical inhibitors present in the tightly compacted central region of the rice bag.* To insure maximum seed viability during spring seeding, growers should endeavour to remove stored seed as quickly as possible after ice break-up and transfer for seeding without delay.

The earliest germinating plants were found May 28th, 1984, at the shallowest, south end of the lake (0.7 m). There were no signs of growth in deeper water, nor at the incoming creek mouth, even though water depth here approached 0.5 m. Regular checks on the incoming water through May, proved this water to be rather peculiar. Very cold temperatures and low conductivity persisted. By June 4th, germination was visible even in 1.5 meter depths. First leaves in shallow areas were now 60 cm long. There were 10 mating pairs of ducks counted on the lake. Heavy infestation of "slough grass" along west shore made sighting of wild rice difficult at times. By June 13th, the first floating leaves reached the surface in the south end. Growth in other areas of the lake remained late and patchy.

Beaver activity at outlet creek was noticed June 13th. A large flock of Sea Gulls were now spending time on the lake. A large number of floating leaves were found blown up

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* (Cardwell, Oelke and Elliott, 1978).

on the south shore. These leaves appeared to be broken or chewed off - winds were moderate. Water lily growth was substantial, especially along west and south-west shores. High winds were noted on June 29. The deep water rice had just reached the surface. Rice plants located in the "bog" creek were just germinating June 29, with a few 10-12 cm long. Plants in the south end began to stand July 3. Two pairs of ducks with 14 young ones made their home on the lake. There was some evidence of stems being chewed July 17. One muskrat was also spotted in south end of lake. Flowering began July 20th. Strong winds and heavy rains were noted on August 6th. Thin patches over the majority of the lake began losing plants the first week in July, but was really noticeable following the wind. Early seeds began forming August 6th with a few kernals ripening by August 13th. Strong winds, some hail, and torential rains struck August 13th. By August 20th, thin patches in 1.5 m+ water laid down in water with immature flowers and died. Heavy animal predation was recorded at the river delta region.

Harvest began August 20th in the south end of the lake. Successive harvests occurred August 28th, August 31, September 5th, 10th, 14th, 18th and 28th. Approximately 225 kg were harvested from a producing area of 1.6 hectares. A flock of migrating ducks continued to feed in the rice until October 18.

V. RESULTS

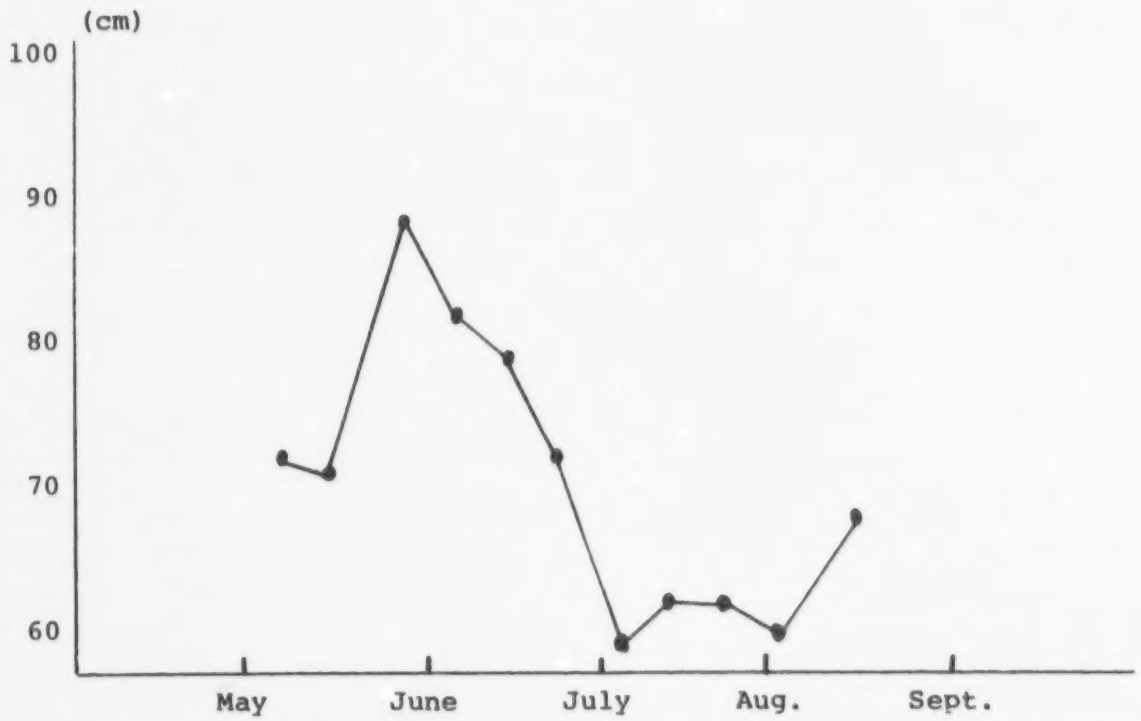
1. WATER FACTOR

a) Water Depth

Depth (as measured by a permanent marker pole) showed a gradual increase from May 1 to a peak on June 4, followed by a steady decline through August 1. Minor fluctuations

throughout the growing period were directly related to precipitation and the continual attempts of beaver to block the outgoing creek.

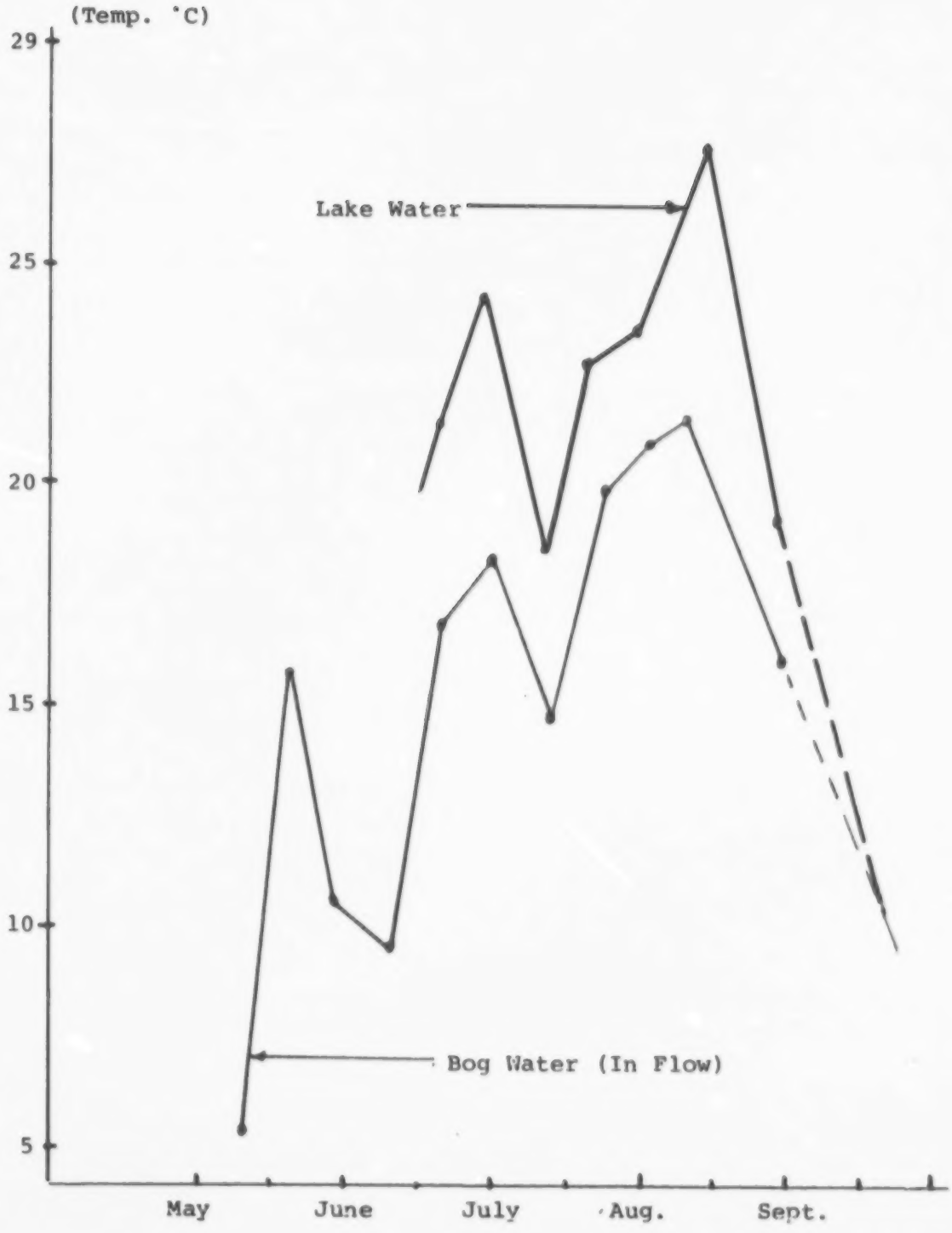
The sudden rise in depth beginning mid May until June 1st was attributed to the increased flow from the muskeg melt, coupled with spring rains. Depth fluctuations is shown in the following graph.



b) Water Temperature

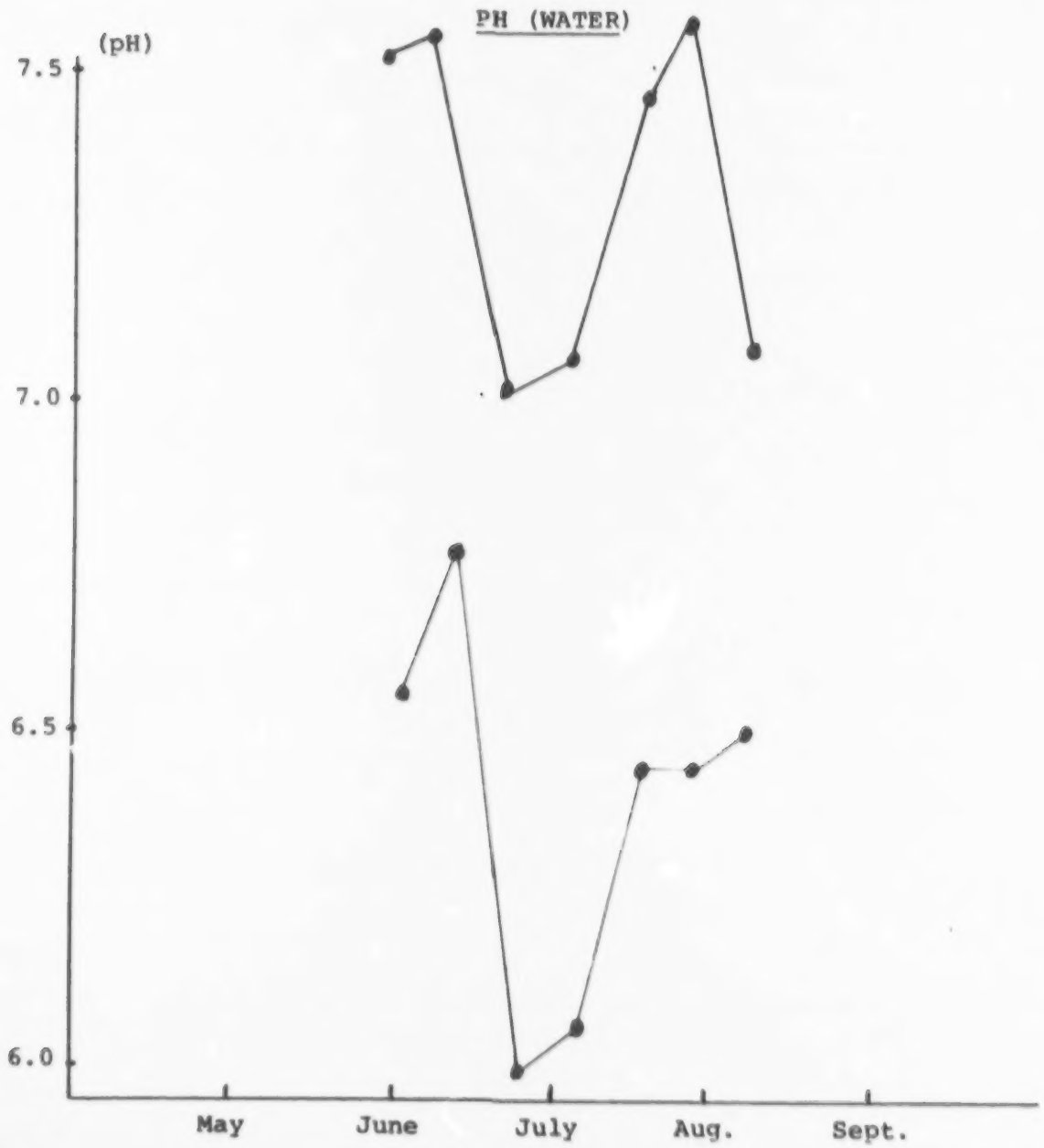
Water temperature as shown in the following graph rose rather quickly from 17°C in early May to 23°C by the end of June followed by a dramatic fall in temperature during the first week in July. The sudden drop of temperature in early June as well as mid July, which deviated from the general pattern, was attributed to heavy rain which could have caused the muskeg melt in the surrounding areas. A normal ascending pattern then developed to a peak of 26.5°C August 3, with a subsequent decline in temperature through harvest. A corresponding pattern was found in the primary feed creek but remained several degrees colder throughout the season. Rice located in the area of this creek showed very late germination, slow development into floating leaf and headed just above the water's surface.

Muskrat predation was high and many heads remained immature. Color of this rice was rather sickly, appearing to be a much lighter green with the occasional yellow floating leaf and stem. These plants were visibly under stress, with cells later dissolving and completely disappearing.


(Temp. °C)
29
25
20
15
10
5
Lake Water
Bog Water (In Flow)
May
June
July
Aug.
Sept.

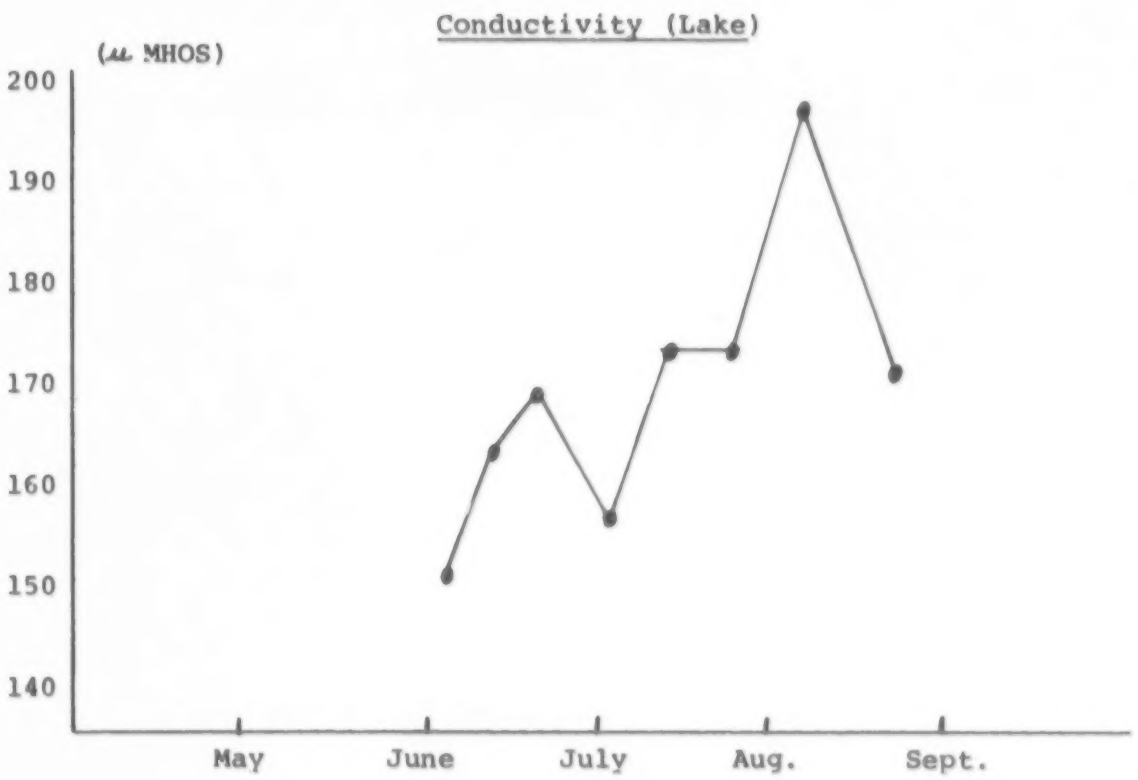
c) Water pH

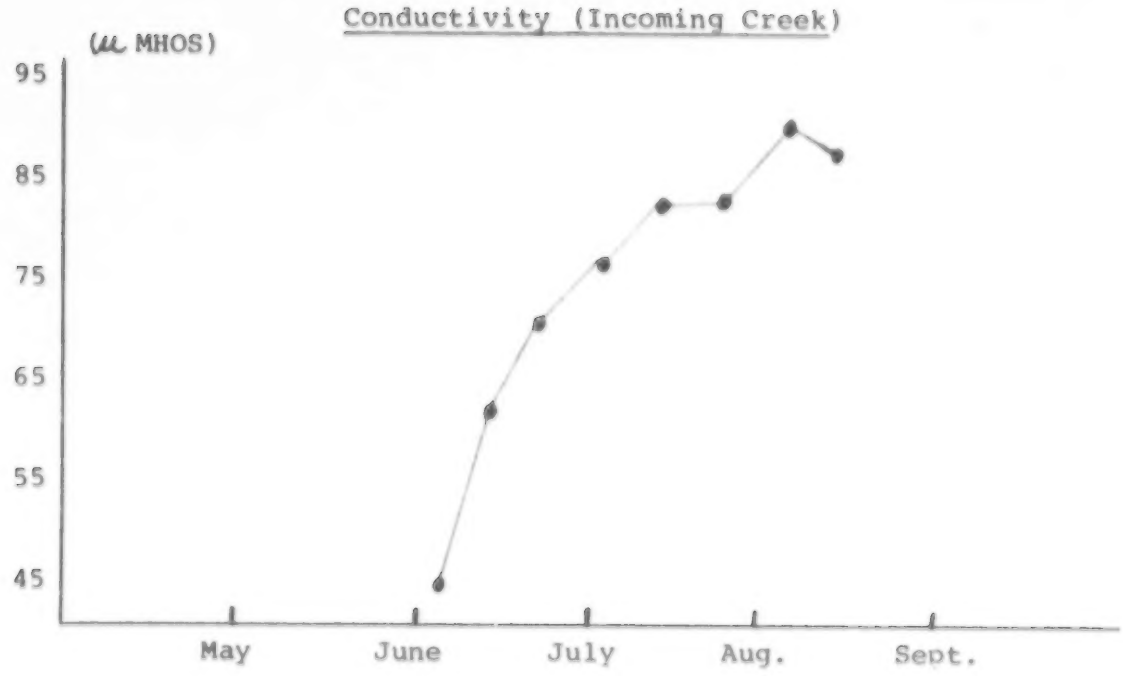
Water pH showed a similar trend to that of water temperature. The sudden drop in pH and water temperature in late June may reflect the sudden influx of cold, deficient "bog" water from the muskeg melt.



d) Conductivity

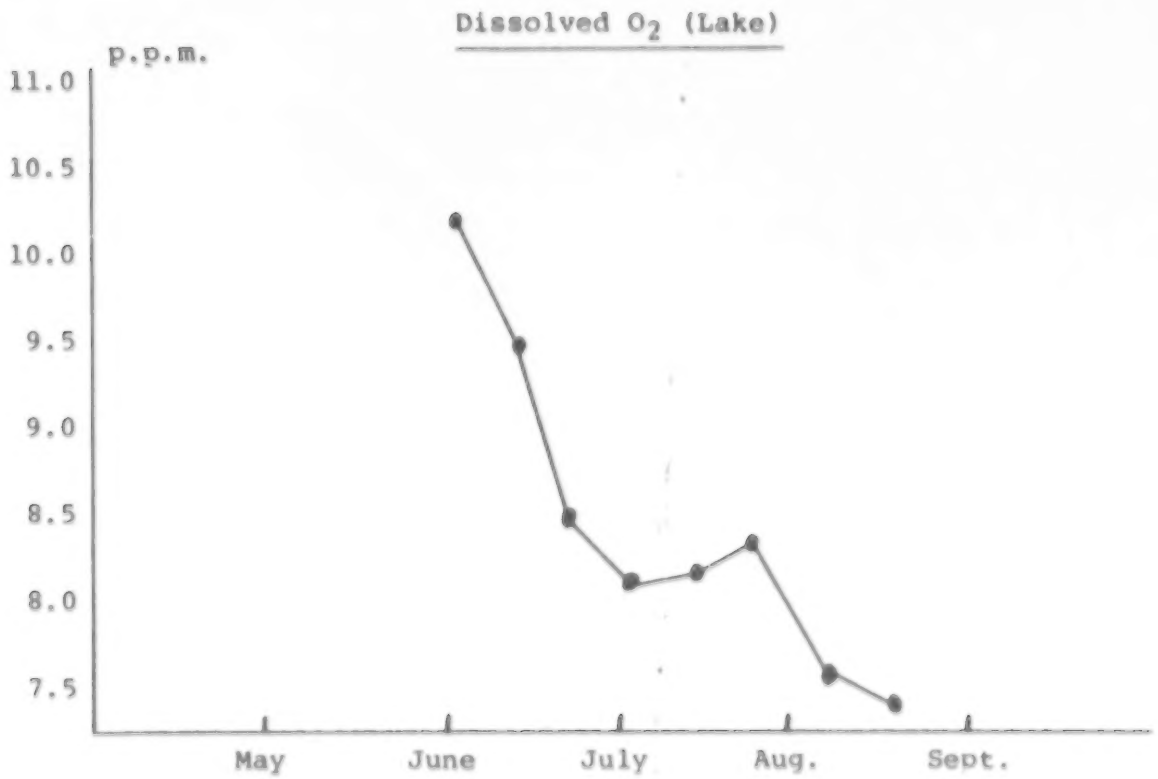
Conductivity records a slight drop by July 4, but recovers quickly and maintains an increasing trend through to harvest. The incoming bog water displays an amazingly low conductivity value, beginning at 45 in June and climbing to only 90 August 3rd.



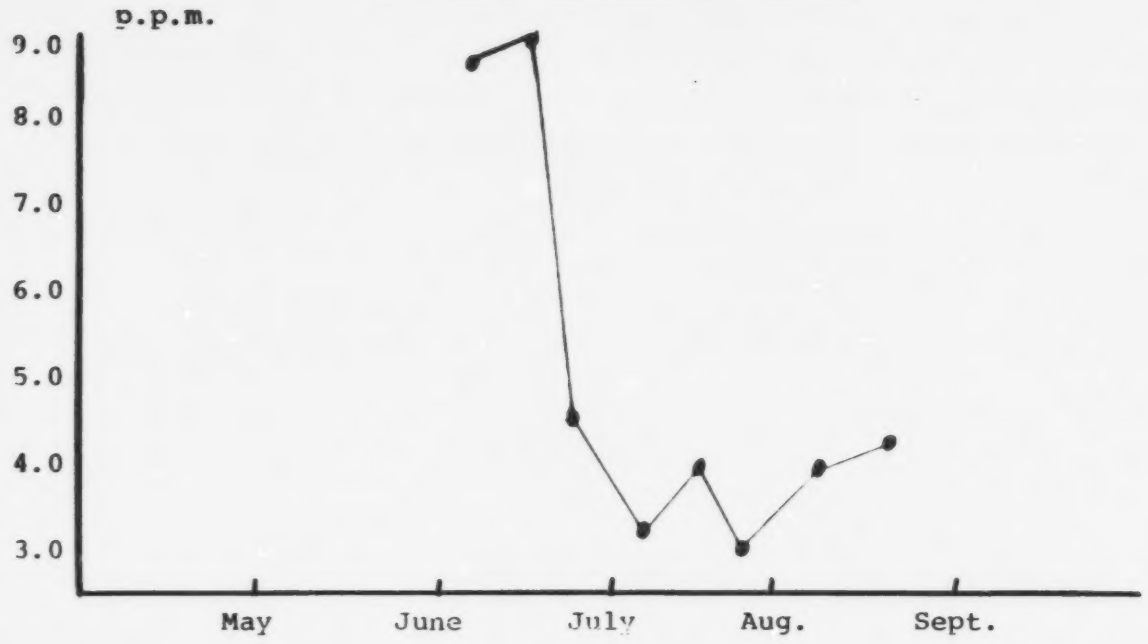

Conductivity (Incoming Creek)
(μ MHOS)
95
85
75
65
55
45
May
June
July
Aug.
Sept.

e) Dissolved Oxygen

Dissolved oxygen reverses previous patterns by showing a general decline throughout the growing season. Bog water at inlet creek remained consistantly lower than the lake with very low levels of oxygen recorded from July 4th to harvest.



Dissolved 0_2 (Incoming Creek)



f) Turbidity

Turbidity did not seem to play an active role in the overall growth cycle of Demchenko Lake. The white disc used in the study was visible to a depth of 1.6 m throughout the season.

g) Complete Water Analysis

Complete water analysis of samples taken at different stages of the growing season showed no significant differences between transects in the lake. Consistently lower values for total dissolved solids, pH, conductivity, Ca++, and water hardness were recorded in the "bog" water. This remained consistent with values for pH, conductivity and oxygen levels recorded on site. These acidic, low nutrient values are not condusive to good growth of wild rice in the river and adjacent to it. Plant stress was clearly visible in these areas as previously discussed.

TABLE 2: WATER ANALYSIS (June 18, 1984)

Transect #	T.D.S. (ppm)	pH	Conductivity (mS/cm)	Concentration of Soluble Ions (ug/mL)						NO3 ppm	HCO3 meq/1
				Na+	Ca++	Mg++	K+	Cl-	SO4=		
Culvert	64	6.6	0.1	14	10	4	3	2	3	.1	0.91
1	128	7.2	0.2	8	28	9	4	3	3	.1	2.18
2	128	7.3	0.2	6	25	9	4	3	3	.1	2.04
3	128	7.4	0.2	5	26	9	4	3	3	.1	2.05
4	128	7.4	0.2	4	26	9	4	3	3	.1	2.04
5	128	7.4	0.2	3	29	10	4	3	3	.1	1.71

TABLE 3: WATER ANALYSIS (August 22, 1984)

Transect #	T.D.S. (ppm)	pH	Conductivity (mS/cm)	Concentration of Soluble Ions (ug/mL)						NO3 ppm	HCO3 meq/1
				Na+	Ca++	Mg++	K+	Cl-	SO4=		
Culvert	77	7.5	0.1	1	20	6	4	3	5	<0.10	1.27
1	134	7.9	0.2	1	32	10	3	3	3	<0.10	2.28
2	128	7.6	0.2	1	30	10	4	4	3	<0.10	2.19
3	128	7.9	0.2	1	29	10	4	3	3	<0.10	2.14
4	128	7.9	0.2	1	29	10	5	4	3	0.38	2.14
5	128	8.0	0.2	1	29	10	3	3	3	<0.10	2.15

2. SEDIMENT FACTOR

a) Sediment Depth

Sediment depth was recorded in all transects to be in excess of one meter with the exception of transects 3 and 4 in the 1 meter plots which recorded sediment depths of 15 cm and 30 cm respectively. Small rocks and gravel underlayed the sediment here.

b) Soil Texture

Soil texture is similar to that normally described as being ideal rice growing areas - a soft, mucky ooze. Color, after air drying, is quite black, a condition occasionally described by experienced growers as being not quite as productive as brown or greyish-brown substrates - others have found good production in dark black soils. The fertility analysis recorded soil texture as being "organic".

c) Sediment pH

Sediment pH varied from a low of 6.2 in the good producing transect #1, to a high of 7.4 in transect #3. Researchers have for some time tried to link water and sediment pH to productivity of wild rice. In this particular study, low sediment pH coupled with high water pH relates to the best productivity in transect #1.

d) Nitrogen (NO_3)

Nitrogen was found highest in transect #4 with a mean value of 15.5. Transect #1 came in second with a value of 6.9, with the lowest value of 1.0 in transect #2.

e) Phosphorus (P)

A recent study by Roger C. Garrod of the University of Manitoba 1984, successfully used phosphorus (P) levels to predict productivity of wild rice. This model fits the Demchenko study rather nicely, with phosphorus levels the highest in transect #1, followed by #5.

f) Potassium (K)

Potassium (K) levels and sulphur (SO_4-S) levels are significantly high through all transects and do not seem to present a limiting factor in production.

g) N, P, K Contents

The combination of all three primary growth nutrients of N, P, and K were found to be the lowest in transect #2, a low producing area when coupled with the 1.5 meter depths.

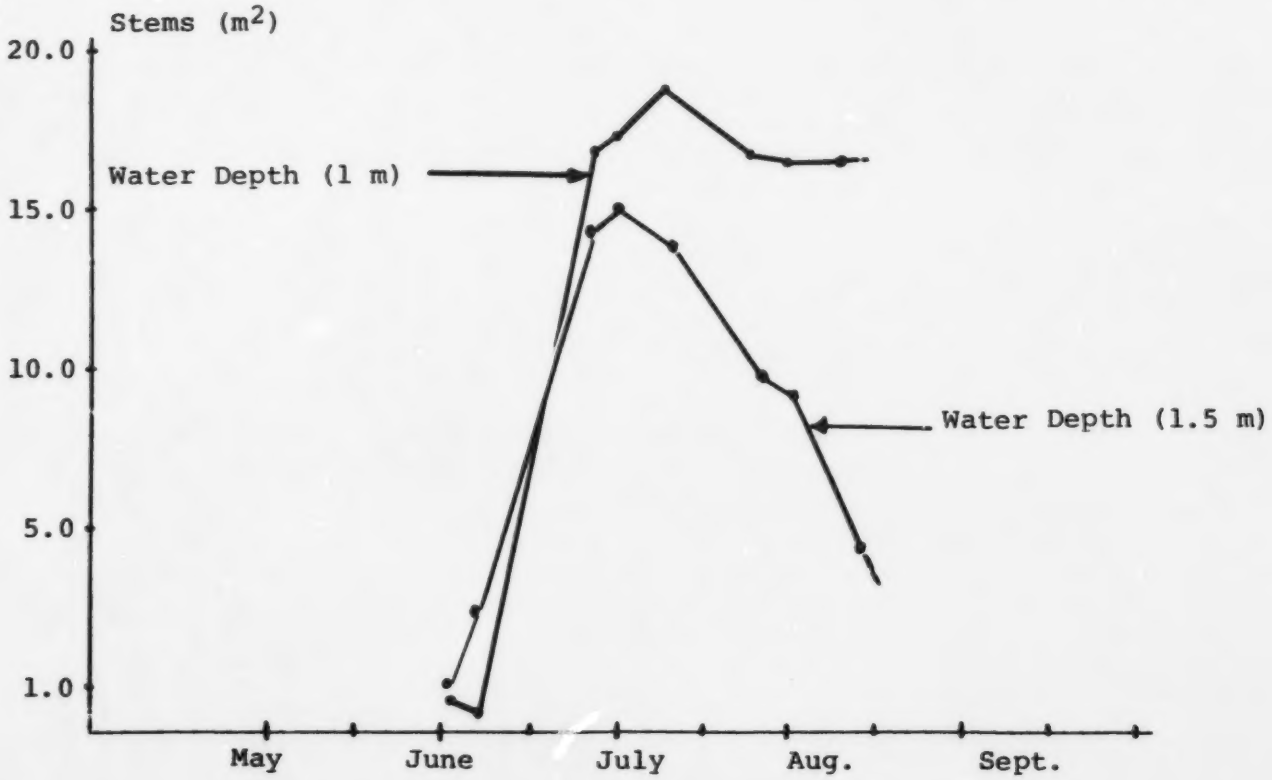
TABLE 4: Soil Analysis - Mean Values

			Available Nutrients (ppm)			
Transect #	pH	Cond.	N.	P.	K.	SO_4-S
1	6.2	.75	6.9	12.5	115	>20
2	7.15	1.05	1	3.5	112.5	>20
3	7.4	1.8	1.9	7	142.5	>20
4	6.5	.65	15.5	7	145	>20
5	6.6	.7	1.6	8.5	157.5	>20

3. PLANT FACTOR

a) Stem Count

Stem counts show both 1 meter and 1.5 meter transects increasing in numbers to mid July. The 1 meter plants remain relatively high while the deeper transects began losing plants as harvest approached. This data, however, is no quite so convincing when each transect is taken separately. With the exception of transect #1, all others, regardless of depth began to lose plants during the first week in July. Transect #1 maintained its plant count, even at 1.5 meters and tillered well in both. This may indicate further variables, such as sediment quality, also playing an important role. Graph of stem counts on all transects at 1.0 m and 1.5 m in depth is shown below:



b) Tillers

Tillering was enhanced by the shallower water, with the exception of transect #4. All others tillered to a higher degree in the 1 meter quadrats, with the greatest number of tillers found in transect #5. Transect #1 remained high at both 1 meter and 1.5 meter depths as shown in table 5.

TABLE 5: MEAN NUMBER OF TILLERS

Transect #	1 Meter	1.5 Meter
1	.50	.285
2	.230	0
3	.166	0
4	.166	.200
5	.714	0
Mean	.3552	.097

c) Stem Length

Plants growing in 1.5 meter depths were visibly shorter (above the surface) than those growing in 1 meter depths. The total length of stems averaged 137.59 cm in 1 meter depths compared to 182.2 cm in 1.5 meter depths, however by subtracting actual depths at this time, we find the shallower plants 50.9 cm above the surface compared to 45.2 cm for the deeper as shown below.

TABLE 6: STEM LENGTH (cm)

Transect #	1 Meter	1.5 Meter
1	166.79	203.85
2	125.0	163.66
3	*-	*-
4	121.0	179.14
5	-	-
Mean	137.59	182.22

*Top of stem and head removed by predators.

d) Seed Production

Overall seed production was better in the 1 meter depths than the 1.5 meter (23.76 seeds/stem compared to 20.2). The majority of seeds in transect #5, 1.5 meter, were immature and would not produce viable seed. Transect #1, 1.5 meter, recorded the highest number of seeds per stem, again indicating another variable affecting seed production.

TABLE 7: NUMBER OF SEEDS (MAIN STEM)

Transect #	1 Meter	1.5 Meter	Mean
1	34.09	42.28	38.19
2	23.72	14.5	19.11
3	7	N/A	3.5
4	24	23.28	23.64
5	30	(21) Immature	25.5
Mean	23.76	20.2	

e) Weight

Total plant weight (Table 8) shows the 1 meter and 1.5 meter plots almost identical at 1.75 grams and 1.79 grams, with plants in transect #1 by far the heaviest. Calculated weights in grams/cm, shows the shallower plots heavier than the 1.5 meter plots, but again with the more robust plants located in transect #1.

TABLE 8: TOTAL PLANT WEIGHT (GRAMS)

Transect #	1 Meter	1.5 Meter
1	4.16	4.26
2	1.41	.985
3	.56	.396*
4	1.21	2.13
5	1.42	1.18
Mean	1.752	1.79
S.D.	1.39	1.51
Var.	1.9	2.29

*Top of stem and head removed by predators.

TABLE 9: WEIGHT - GRAMS/METERS

Transect #	1 Meter	1.5 Meter
1	1.9	1.79
2	1.0	.50
3	-	-
4	.77	.988
5	-	-
Mean	1.22	1.09

f) Stem Diameter

Stem diameters remained consistant with other plant characteristics showing 1 meter plots superior to the 1.5 meter plots with the exception of transect #3. Transect #1 again displays the more vigorous plants.

TABLE 10: STEM DIAMETER (cm)

Transect #	1.0 Meter		1.5 Meter	
	Base	Top	Base	Top
1	3.99	2.20	3.45	2.37
2	2.26	1.39	1.5	1.15
3	1.38	.9	1.76	1.8
4	2.67	1.43	2.68	1.46
5	2.34	1.38	1.4	-
Mean	2.52	1.46	2.15	1.35

g) Flower Length

Overall flower length again follows the model that water depth is a contributing factor in growth characteristics. Flowers in the 1 meter plots were on the average 2.02 cm longer.

TABLE 11: FLOWER LENGTH (cm)

Transect #	1 Meter	1.5 Meter
1	41.97	50.07
2	34.00	26.16
3	15.0	-
4	33.5	44.64
5	38	31.5
Mean	32.49	30.47

h) Leaf Characteristics

Leaf characteristics do not follow the previous trend. Width, sheath length and blade length all show larger values for the 1.5 meter depths. Several theories on this phenomenon may be presented, but a factual hypothesis is not available based on information derived from this project as shown in tables 12, 13 and 14.

TABLE 12: LEAF WIDTH (cm)

Transect #	1 Meter	1.5 Meter
1	12.52	11.53
2	8.15	6.63
3	4.66	8.66
4	7.14	10.05
5	9.8	5.5
Mean	8.4	8.47

TABLE 13: SHEATH LENGTH (cm)

Transect #	1 Meter	1.5 Meter
1	32.66	47.76
2	39.19	30.31
3	40.33	55.3
4	34.28	45.5
5	43	38.5
Mean	37.89	43.47

TABLE 14: BLADE LENGTH (cm)

Transect #	1 Meter	1.5 Meter
1	67.83	-
2	69.42	43.14
3	54.33	99.5
4	57.2	82.3
5	74	69.5
Mean	64.56	73.61

VI. CONCLUSIONS - RECOMMENDATIONS:

1) Water quality of the lake, including temperature, pH and conductivity, is susceptable to dramatic fluctuations directly proportionate to water quality of the inflowing creek or spring. Where test seedings in, or adjacent to inflowing waters have been unsuccessful, try a test seeding in several other appropriate areas of the lake some distance away from the creek or where incoming water quality is improved.

2) Because of the reduced capacity, these small lakes are susceptable to rather sudden increases in water depth following spring break up, the muskeg melt and precipitation. With slow moving drainage creeks, they are also very slow to recover from such increases. Be prepared for these by maximizing flow out of the lake as early as possible in the spring and following precipitation.

3) Where low soil nutrients are coupled with water depths in excess of 1 meter, wild rice productivity is limited, and should be avoided. Where soil nutrients are high and water levels approach 1.5 meter depths, limited productivity may be expected, but establishing a permanent stand of wild rice may be frustrating and expensive. Heavy seed application rates may be of some assistance in establishing a crop. Take care to seed only areas well protected from wind and waves and where weed competition is limited.

4) Where plants show visible signs of stress in the floating leaf stage (eg. slow growing, pale color, dead leaves and eventually a dead plant) soil sampling may be of some value in determining the future viability of the lake. At this point, it appears that soil phosphorous level is a good indicator of plant performance.

5) The importance of water levels can not be overstressed. Establish a permanent depth marker pole in the lake and <u>check it regularly</u>. Where drainage systems and current legislation permit, maintain levels at .5 meters (20") to 1 meter (39").

WILD RICE THINNING*

(FarmLab Project NU 84-06 (720))

I. BACKGROUND

After 2 - 3 favorable crop years, wild rice stands have traditionally shown a marked decrease in production largely due to overcrowding. The effects of this have caused, in many instances, complete and total crop failure for at least one year, and certainly reduced yields from one to several years.

Thinning wild rice stands has proven to be a successful and necessary operation in the Minnesota paddies to maintain maximum crop yields each year. Thinning wild rice in Saskatchewan lakes and rivers, has for many years, been discussed by the more established growers, as being one of the foremost problems in the industry. Varying configurations of lake bottoms, including rocks, stumps, dead heads, beaver lodges, muskrat push-ups, wild rice straw cover and other debris all provide unique problems in attempting to thin heavy stands of volunteer wild rice.

II. OBJECTIVES

1) To provide for an on-site Field Day demonstration for extension purposes.

2) To evaluate the effectiveness of the tool in an effort to design a more positive and efficient method of thinning.

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* This project was undertaken by the Northern Agriculture Unit, under the direction of Pab Orcajada, Wild Rice Agrologist. Field work, analysis and initial preparation of report was done by Bill Plunz, Field Worker.

3) To collect data that will document the effects of thinning and demonstrate the value of such practice.

4) To define how many plants per square foot (per square meter) provides the best growth and production in Saskatchewan lakes and rivers.

III. THE CO-OPERATOR

Mercer River Rice Ltd., which operates almost 500 acres of wild rice farm was chosen as the co-operator for this particular project. Mercer River Rice Ltd., has been designing and testing various methods of thinning equipment for the past three years. During an attempt to remove dead, floating straw in the spring of 1983 with a rake type device, it was discovered that this tool was also effective in pulling out plants in the floating leaf stage, especially where volunteer stands were very thick. Visual observations appeared to show healthier looking plants, larger heads, and more tillers. A higher yield in these areas was predicted, but no scientific analysis was done at this time.

IV. EQUIPMENT

Equipment used in the project consisted of regular pontoon type boats, air driven - the same as used for the fall harvest operation. Each boat was fitted with a "rake" device which attached easily to the speed head arms at the front of the harvester. The "rake" was constructed from 1" x 2" steel tubing 18 feet (5.4 m) long, with 1 inch round pipe, 2 feet (.6 m) long welded at intervals of 6 inches (15 cm). Operating depth could be varied at will by activating the speed

head arms. The angle of attack could also be varied through use of the hydraulic system.

V. METHOD

Test strips approximately 200 yards (180 m) long by 60 yards (54 m) wide were staked and flagged throughout the heavy stands of wild rice on the Mercer River farm. "Control Zones" of similar size were staked and flagged. These zones would remain untouched through the thinning process and subsequent growing period.

As the air drive boats approached 9 mph (14.5 km/hour) the rake was lowered into the water to a depth of 14 inches (35 cm) and continued through the test area. The large volume of floating leaf rice was released from the rake when full by raising it from the water and tilting it back.

The thinning process began June 15th and continued through June 20th. The rice at this time was in advanced floating leaf stage. The procedure was stopped when adjacent control zones were beginning to stand.

Six square meter quadrats were set up at permanent sampling stations, three in the thinned strips and three in the control zones. The stations were chosen at random and without bias although the distance between the thinned quadrat and non-thinned quadrat was kept to less than 150 feet (45 m) in each area to minimize the effects of environmental and sediment variables. Water depths were then measured to insure a variance of less than two centimeters between quadrats.

Stem counts and observations were taken July 13, 1984 and August 16, 1984. Twenty-five plant samples were chosen from each quadrat at random and without bias on August 16, 1984,

one day prior to harvest beginning. These plants were air dried and later analysed under the following criteria: Number of seeds, length of male and female rachis, subapical and basal stem diameter, stem and root weight, internode length, leaf characteristics, number of stem and root tillers, presence of prop roots and other calculated measurements.

Additional visual observations were taken throughout the growing period and harvest by the Farm Lab co-operator.

VI. RESULTS

A) Mechanical Operation

The "rake" showed some promise as a thinning tool but did have its limitations. When straw conditions from the previous year's crop persist, either floating or partially submerged, the "rake", or any other device that would drag through the water, may be deemed useless. Plugging with dead straw occurs rapidly in these conditions and makes thinning new plants relatively impossible.

Where straw conditions are light or non existant, the "rake" was found effective in pulling new plants in floating leaf. Plants still partially submerged were almost always missed, giving rise to a new crop of floating leaves the following day or two. As the "rake" became plugged with pulled plants, it became less effective and had to be cleaned by lifting from the water. As many as 15-20 passes over the same strip were required to pull 95% of the floating leaf plants. This mild disturbance seemed to promote growth of partially submerged plants and the entire operation had to be repeated on a daily basis for a period of six days. Tine spacing was not altered as the operators felt that a narrower

spacing would plug too rapidly and a wider spacing would not be as effective in pulling plants.

B) Field Day

Twenty-seven people were on site to witness the thinning operation take place. A one hour discussion period followed lunch. This was a beneficial exercise where more experienced growers could discuss with less experienced, the problems and benefits associated with thinning. Other problems such as straw removal, water control and the use of chemicals and fertilizers were discussed.

C) Reseach Analysis

(i) Stem Counts:

Stem counts July 13, 1984 showed that control zone plots had an average of 161.6 stems/square meter. The highest count of 180/square meter was found in plot #2 and the lowest of 145/square meter in plot #1. Stem counts in the thinned areas showed that the process was successful in reducing the stand to an average of 121.6 stems/square meter. The lowest count was found in plot #3 at 110 stems/square meter. The entire operation reduced stem counts by an average of 40/ square meter.

August 16, stem counts revealed that even though the number of plants had been reduced by 40/square meter, the number of producing stems in the thinned area increased from 121.67 to 168.67, an average of 47.

The number of stems in the non-thinned area improved only slightly from 161.67 to 175 stems/square meter, an average of

13.3. The increased stem count in the thinned area may be attributed to increased tillering.

(ii) Plant Analysis:

Thinning did indeed promote tillering. An increase from .045 to .181 occurred in test plot #1, along with test plot #3, showing the best increase from .095 to .368. (Note: test plot #3 had been thinned to the highest degree - 110 stems/ square meter). Plot #2 remained the same at .227.

Stem length increased only slightly on the average in the thinned areas from 147.47 cm to 149.95 cm. Test plot #3 again showed the best results, with plot #1 actually showing a decrease in height in the thinned area.

Total plant weight, stem diameter, overall flower length and leaf blade length all showed consistant increases in size in the thinned plots. Conversely, leaf width and sheath length were reduced slightly by subjecting them to the thinning process.

The main objective of the experiment was to show whether thinning would have a positive influence on production. The result was that even though thinned plots generally showed a slight increase in growth characteristics, overall seed production decreased from 27.97 seeds/stem to 23 seeds/stem. On an individual basis, plot #1 decreased from 34.35 seeds to 20.04, plot #2 - 29.85 seeds to 22.71 seeds. Plot #3 (again the one thinned the most) increased in seed production from 19.72 to 26.26, but not sufficient to make up for losses in the other two plots. Unfortunately the weight of individual seeds was not available since plants were pulled for analysis just prior to harvest. The majority of seeds, although starting to fill, were immature at this time.

A computation of total production per hectare showed that where thinning reduced the stand to 125 and 130 stems/square meter in plots #1 and #2, a reduced yield was experienced. In plot #3, where thinning reduced stem counts to 110 stems/square meter, an increase of 958 kg/ha was found.

These reduced yields may be attributed to the "non-selective" thinning taking place through use of the "rake". By destroying all plants in floating leaf over a period of six days shortens the natural gorwing period resulting in a poorer yield. Where stem counts approach less than 110 stems/square meter, lack of competition may provide superior growing conditions and an increased yield. (Plot #3).

VII. CONCLUSIONS

1. A much more effective and efficient thinning equipment needs to be designed and developed.

2. A more efficient method of thinning should be explored.

3. Thinning did enhance tillering, but plant count per square meter was not reduced sufficiently enough (atleast 50 plants per square meter), to promote good plant growth and high yield.

4. Thinning at the floating leaf stage resulted in the retardation of growth of new plant and may have contributed significantly to low yield.

5. Field days and/or demonstration, as in this project has proved to be an effective extension tool.

TABLE 1: STEM COUNT OF THINNED AREA (STEMS/SQUARE METER)

Plot	July 13	August 16	Increase
1	125	170	45
2	130	170	40
3	110	166	56
Mean	121.6	168.6	47

TABLE 2: STEM COUNT OF NON-THINNED AREA (STEMS/SQUARE METER)

Plot	July 13	August 16	Increase
1	145	150	5
2	180	200	20
3	160	175	15
Mean	161.6	175	13.3

TABLE 3: SHOWING GRAPH OF THINNED AREA (STE

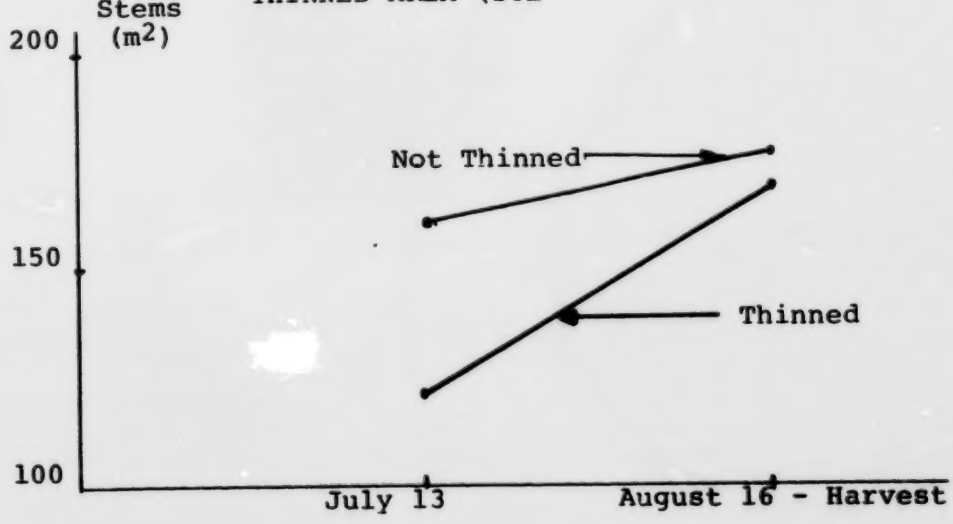


TABLE 4: COMPARATIVE TABULATION OF MAJOR FACTORS

Average number of tillers

PLOT #	THINNED	NON-THINNED
1	.181	.045
2	.227	.227
3	.368	.095
Average	.259	.122

Stem Length (cm)

1	134.9	161.95
2	146.38	145.2
3	168.57	135.27
Average	149.95	147.47

Number of Seeds (Main Stem)

1	20.04	34.35
2	22.71	29.85
3	26.26	19.72
Average	23.0	27.97

Total Weight (gm)

1	2.17	2.59
2	2.14	2.67
3	3.41	1.63
Average	2.57	2.29

Number of Seeds (Tillers)

	1st	2nd	
1	36.66	(51)	0
2	33.0		30.5
3	26.4		0
Average	32.02		10.17

TABLE 4: (Cont'd) - 111 -

Stem Diameter (Base) (mm)

PLOT #	THINNED	NON-THINNED
1	3.08	1.07
2	.694	3.74
3	3.27	.63
Average	2.35	1.81

Stem Diameter (Top) (mm)

1	1.68	.50
2	.506	1.74
3	1.83	.38
Average	1.34	.87

Flower Length (cm)

1	30.68	36.30
2	36.26	37.43
3	37.68	29.86
Average	34.87	34.53

Leaf Width (mm)

1	9.78	11.38
2	9.95	10.31
3	10.73	8.9
Average	10.15	10.20

Sheath Length (cm)

1	35.84	41.07
2	36.95	43.54
3	42.77	36.3
Average	38.52	40.3

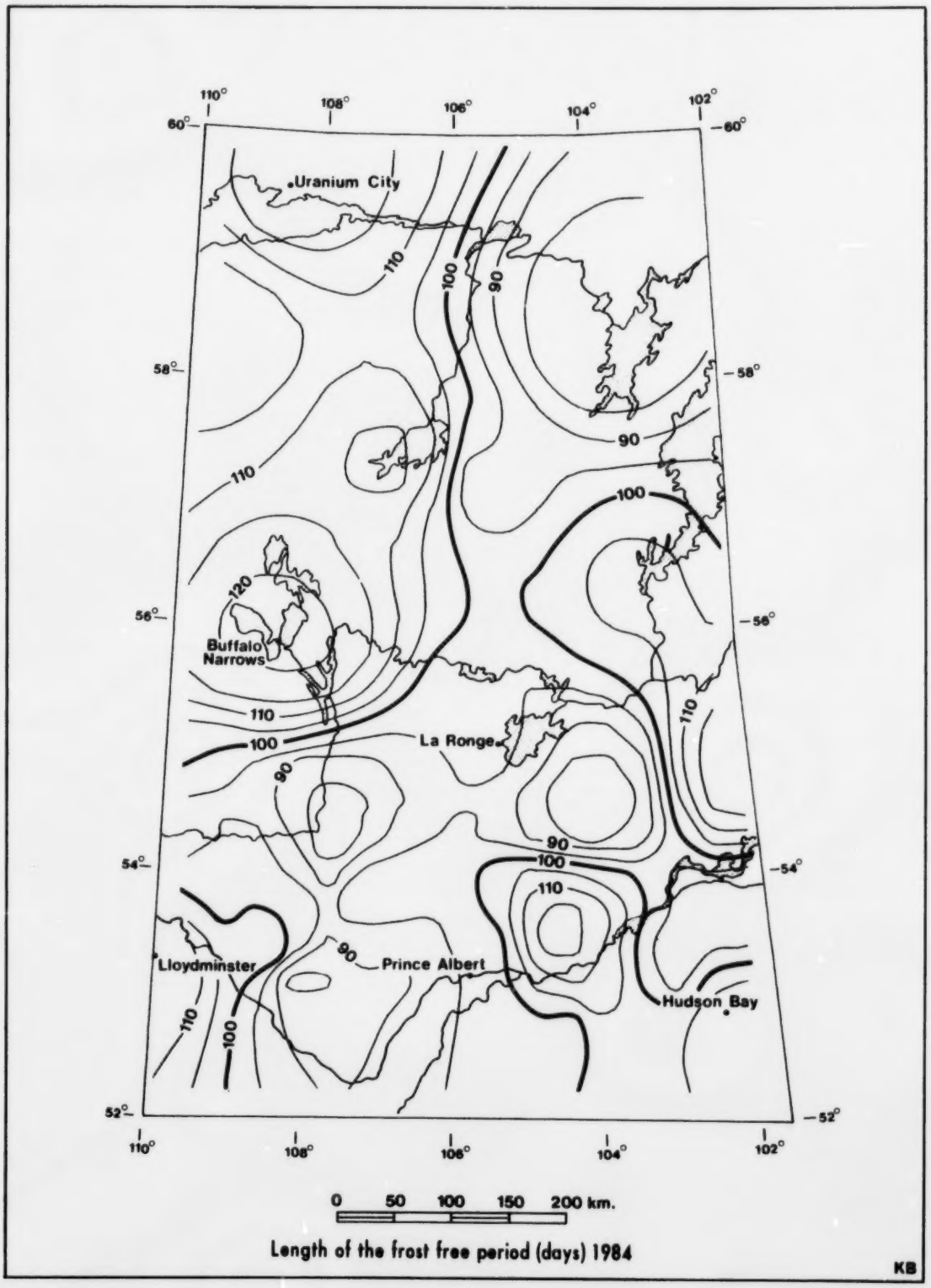
Blade Length (cm)

1	56.42	63.0
2	61.36	61.9
3	64.44	49.5
Average	60.74	58.13

TABLE 5: YIELD COMPUTATION (KG/HA)

Plot #	Thinned	Not Thinned	Increase or Decrease
1	3,020	3,793	-773
2	3,285	4,625	-1,340
3	3,366	2,408	+958
Average	3,223	3,608	-385

* Green weight average = .0771 g/seed computed by Archibold - Weichel, 1983.



Length of the frost free period (days) 1984

KB

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